CHAPTERS

ON

PAPERMAKING.

Vol. III.

CLAYTON BEADLE.

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Chapters on Papermaking

VOL. III.

COMPRISING A SHORT PRACTICAL TREATISE IN WHICH BOILING BLEACHING, LOADING, COLOURING, AND SIMILAR QUESTIONS ARE DISCUSSED

BY

CLAYTON BEADLE

Lecturer on Papermaking before the Society of Arts, 1898, 1902 *and* 1906; *at the Papermakers' Exhibition,* 1897; *at the Dickinson Institute, on behalf of the Hertford County Council,* 1901, *and at the Battersea Polytechnic Institute,* 1902; *awarded the John Scott Legacy Medal and Premium of the Franklin Institute, by the City of Philadelphia, the Gold Medal of "La Société pour l'Encouragement de l'Industrie Nationale" of Paris, the Silver Medal by the Council of the Society of Arts in* 1906, *and other Medals and Awards.*

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PREFACE.

The author wishes to urge that the chief value of this volume is to be found in the fact that it embodies the opinions of men who are continually confronted with the problems under discussion during their everyday work, and that these men represent the paper trade in every sense of the word, as, in addition to buyers and sellers of paper, all classes are represented, from prominent mill-managers to those occupying the humble positions of "fillers in."

The work cannot for the most part lay claim to literary merit, as to edit, alter, or otherwise render into better English many of the comments herein chronicled at great labour and trouble by the "horny hand of toil," would be to rob the work of a great deal of its interest and utility, as well as possibly to misinterpret the intended meanings of many of the writers. Furthermore, the most expressive way of describing most paper-making processes is not always capable of being rendered into good English, and the majority of those who are more or less familiar with such matters would prefer to see them described in the ordinary language of the paper mill.

The author is of opinion that readers will gain as much benefit by "reading between the lines" of the various answers as by seeking for direct information. In other words, the

answers are as useful by way of "suggestion" as "instruction," and should set young papermakers thinking.

It is to be hoped that these volumes will prove of service to those who contributed in the first instance to a discussion upon these questions, as well as to those who read and study these questions for the first time.

The author wishes to record his thanks to his colleague, Dr. H. P. Stevens, for his assistance in connection with the work of editing these notes.

Laboratories: 15, The Boro',
London Bridge, S.E.
August, 1907.

CONTENTS.

GENERAL INTRODUCTION TO VOLS. III. AND IV.

THE work, the outcome of which has resulted in the production of this and the succeeding volume, was started in 1902 as a result of a conversation which the author had with Mr. James Duguid, the then editor of PAPER AND PULP.

After taking the opinions of leading members of the paper trade who were found to be favourable to the scheme, an attempt was made to conduct correspondence classes. The scheme was not based upon correspondence tuition as generally understood; the author called his system "Test Questions," the object being to set a number of practical questions which should be a test as to the knowledge and capacity of those who answered them. The further object of these test questions is to assist paper-mill workmen to prepare themselves for the examination on paper manufacture by the City and Guilds of London Institute. As the work advanced it became evident that the various workers were far more interested in vying with one another in their answers than in seeking to prepare themselves for any after examination.

It was arranged that the names of the writers of the papers should not be made known, and that there should be no direct correspondence between the examiner and those who sent in their answers, the only medium of their correspondence being the columns of PAPER AND PULP, so that any comments and criticisms made by the examiner could be read by all readers of the journal. Marks were given to each of the answers, and the winner of the series was awarded a prize. On the award of the prizes, with the consent of the first three on the list, the first three names were published. The papers were freely quoted from, and some of special value and interest were published *in extenso*.

Many of those who entered were working men, without any experience of preparing an examination paper, some possessed

very poor literary style, others showed some ability to express their views, but, whether illiterate or not, the great bulk of the answers showed considerable labour and thought, and reflected the greatest credit on the workers' industry. As the examiner was conducting Test Questions with the primary object of helping lame dogs over stiles, in order that an illiterate working man might, if he possessed the knowledge, have as good a chance as an educated manager's son, he judged the answers entirely on their value, as conveying, or seeking to convey, information. But education must tell in the long run, as it gives a man the power to think as well as to express his thoughts. Many of the writers undertook special researches for the purpose of throwing light upon the questions. The answers to the first questions were comparatively poor, due, no doubt, to the inability of the writers to express their views, but the majority gained some experience and profit by the general interchange of opinions resulting from the publication, and comments upon one another's answers. As a result the answers slowly but steadily improved. All were specially cautioned against divulging any trade secrets or stating anything that might be regarded as special information belonging to their firm. The author cannot recall a single instance in which such information was tendered in the answers. Furthermore, many employers expressed themselves in favour of the system, and in no case can the author recall a single instance in which the employer raised an objection to his workpeople making use of the system.

It has been urged that correspondence tuition tends to discourage class teaching, which latter is considered far more valuable, and consequently correspondence teaching should not be resorted to. As proof against this view, the author found that the greatest number of students, in any one locality, who availed themselves of the correspondence tuition, were, at the same time, attending lectures and classes conducted privately by their employers. It does not appear that correspondence tuition will in any way interfere with the lecture attendance, but it would appear, rather, that one will assist the other. There are many things to be said in favour of correspondence tuition; for instance, there are many difficulties to be contended with in classes, which do not occur in correspondence tuition. The classes are few and far between, and not accessible to many, whereas correspondence teaching is equally accessible to students in all parts of the country. Correspondence tuition is perhaps a misnomer; in so far as it relates to the scope of these volumes, the attempt has

rather been to help and guide mill-workers by setting them leading questions of a practical nature. The average paper-mill worker, however thorough his practical knowledge may be, requires practice in constructing his answers before he enters for the examination.

Apart from actual aid for examination purposes, "test questions" may have a wider and more important scope—namely, that of stimulating inquiry. The worker has the questions before him, and he goes about his everyday work in the mill and thinks them over. His own work may have some bearing on the questions set him; they are not sprung upon him all of a sudden, as at an examination. He has plenty of time to think them over before he need answer them.

It has been a great source of gratification to the author to meet those who took part in the test questions and to hear that the training and experience so acquired has proved to be of so much benefit. The author is acquainted with the names and addresses of the various workers who supplied the answers. In the text each is referred to under a letter. Some of these gentlemen have made the author's acquaintance since the answers were published.

The following is a list of the "test questions" set and commented upon in the manner above referred to, the details of which are published in this and the succeeding volume:—

Vol. III.

1. Give your views of the relative value of "brass" and "steel" beater bars for Hollanders.

2. What speed (in revolutions per minute) do you recommend for a Hollander beater roll? Does the size of roll, and number and arrangement of bars, affect the question?

3. What do you think of Prussian blue for colouring paper? What papers would you use it for? Under what conditions do Prussian blue papers fade?

4. Can you easily demonstrate, by means of a hand mould, the effect of lowering the breast roll? Explain why a slight lowering of the breast roll will have so much effect upon the removal of water.

5. Why does loading make some papers more opaque than others? Give instances.

The following question is set for those who care to exercise their

ingenuity and test their ability to unravel more difficult problems, such as we might find set in the Honours Grade. Since the primary object of undertaking a correspondence class is to help and guide the mill-workers, the more difficult questions will be dealt with separately, and the following question therefore does not count in the competition for the prize offered by "Paper and Pulp:"—

6. A "furnish" for writings contains 100 lbs. of commercial terra alba per 400 lbs. of dry fibre. A small sample of the terra alba in question, when burnt, will be found to yield 55 per cent. of ash. The stuff is diluted in chest with 23 parts of water for every part of dry fibre. The web, as it passes on to drying cylinders, consists of 28 per cent. dry material and 72 per cent. of water (for purposes of calculation we must assume no loss through leakage, etc., or dilution of back-water, other than that necessary to make up for moisture in web of paper). After a run of 5 tons of paper (total weight at cutter), the machine is shut down, and the terra alba found collected on sand tables and in saveall, etc., weighs 320 lbs. An average sample of this, on burning, is found to yield 35 per cent. of ash. What ash would you expect to find in the finished paper? Show details of calculation, and where losses occur and how.

7. What is the exact influence of alum upon gelatine, both before and after its application to paper? How does the use of alum enable us to regulate the amount of gelatine absorbed by the paper?

8. Give your reasons for and against raising the temperature of bleach in the poacher. What precautions would you consider necessary?

9. What is the action of a refining engine as compared with that of a Hollander? How far can refiners be made to do the beating with advantage? For what class of stuff would you recommend the use of refiners?

10. Does rapid agitation assist bleaching? If so, why?

11. What is the effect of heating the stuff as it passes on to the paper machine, and why should this produce a change in its behaviour on the machine?

The following more difficult question is not for competition, but to test the capabilities of those who might be disposed to enter for the London and City Guilds Examination (Honours Grade):—

12. Give your views of the comparative merits of two well-known systems of soda recovery.

13. How do you account for paper becoming electrified during manufacture; and what steps would you take to prevent it?

14. Why are some papers more transparent than others? Give instances as well as reasons.

15. What influences the "life" of machine wire? Give an instance with full particulars.

16. What is the action of edge runners, and for what special purposes would you recommend their use?

Vol. IV.

17. Why are some papers lighter, bulk for bulk, than others? Give instances.

18. What are the special qualities and uses of "art" papers?

19. What papers are improved and what papers are deteriorated by keeping in stock? To what is the change due?

20. In what instances would you use lime for boiling? Give your reasons.

21. How can you control the mark of a "Dandy"? Make some general remarks on the management of the "Dandy."

22. What are the comparative merits of "machine" and "hand" cut rags from all points of view?

23. What do you consider to be the cause of froth or scum on the machine? Of what does it consist? And how can it be prevented?

24. What harm is there to the paper if the scum is allowed to accumulate?

25. Give the amount of water (in gallons per ton of finished paper) required for any quality of paper you like to choose, and show what is required for the different stages of treatment, beginning with the boiling and finishing with the water used on the machine?

26. Make some remarks upon the management of suction boxes with different kinds and qualities of paper.

27. How can you control the shrinkage of a paper, both in the "machine" and "cross" direction during its manufacture on the machine?

28. How far is it possible to make a paper, either by Fourdrinier or cylinder machine, which, when once made, neither expands nor contracts with change of moisture in the atmosphere?

29. How far is it possible to make a paper on the Fourdrinier machine which does not stretch when tested for "breaking strain"?

30. How far is the quality as mentioned in question 28 (*i.e.*

expansion or contraction with moist or dry air), connected with the quality as mentioned in question 29 (*i.e.* stretch when tension is put upon the paper)?

31. The qualities of paper for commercial purposes are sometimes judged by their "breaking strain," at others by their "bursting strain," and at times by the amount of "stretch" which they undergo when tested for "breaking strain," and finally, both by "breaking strain" and "stretch" combined. Discuss the relative advantages of these different methods, and give your own opinion as to what particular class of paper (if any) each method is with advantage applied to.

32. What paper-testing machine do you prefer to make use of? Give your reasons for any particular preference.

CHAPTER I.

"BRASS" AND "STEEL" BEATER-BARS.

Relative merits—Wearing qualities—Rusting—Pulp Discoloration.

QUESTION 1.—*Give your views of the relative value of "brass" and "steel" beater bars.*

As one of the writers suggests, the word "brass" is used in a generic sense, and may be taken according to its popular acceptation in this connection to mean any compositions used for beater-bars containing copper. These number among them alloys such as bronze, Kentish metal, Manganese bronze, etc. Those who can draw useful distinctions between these various alloys in their behaviour for beater-bars add materially to the value of their answers. I do not think much of the argument about "verdigris;" it is seldom, if ever, found to any extent on beater-bars. There is nothing in the suggestion that brass is to be objected to on account of the formation of "verdigris," as a deposit or coating of such a nature is seldom if ever met with.

C, in common with many, appears to conclude that the chemicals are the only cause of the rusting of the steel bars bringing about the discolouring of the wood pulp. There are other causes. According to the most sustained views, rusting is commonly due to the joint presence of moisture, air (*i.e.* oxygen), and carbonic acid. It is said that steel immersed in water without oxygen and carbonic acid dissolved, cannot rust.* Oxygen

* The chemistry of rusting is not properly understood, and leading authorities differ as to whether the presence of CO_2 is essential, but the recent experiments of Moody all point to the presence of CO_2 as essential to the rusting process. Moody has shown that iron may be preserved indefinitely in moist air from which all traces of CO_2 have been removed by adopting every possible precaution, but directly a minute quantity of CO_2 is introduced, the bright surface of the metal becomes tarnished, and rusting proceeds apace. See papers published in the TRANSACTIONS OF THE CHEMICAL SOCIETY.

alone dissolved in water will not rust, but requires carbonic acid in addition. These two gases are always dissolved in water that is agitated by the beater roll. The conditions are therefore favourable for the ordinary rusting, apart from any chemicals. "Steel should be cheaper and last longer than brass." Such remarks as these do not count for much in an answer. Is steel cheaper in the long run, and does it last longer than brass? A complete answer should substantiate any such statement.

D makes a statement omitted by the others, namely, that after the beater has remained idle for a time and restarted, "rust comes away in large quantities where steel bars are used." This is a sensible remark, and offers one reason for not using steel bars for better class papers. My remarks about rusting without chemicals apply here.

It is refreshing to read definite statements such as **E** gives, that steel bars cannot be used for photographic paper on account of the slightest trace of iron being ruinous; also that brass bars can be used with advantage for long beating, for greasy stuff, etc. He does not generalize too much, but gives exact statements. There is a great deal, however, that might have been said from an engineering point of view.

F gives other useful aspects, such as that the brass bars do not get eaten away, and consequently keep their edge. The edge becomes more of a square edge as the face is worn down, and is useful for some classes of beating. The steel edge gets blunted through corrosion. His final remarks are to the point. "The first cost of phosphor bronze is great, but when renewing the bars there will not be so much cost, because of the extra price that can be obtained for the old bars when taken out."

H states that the stuff is more mellow and clean when using brass bars, and more suitable for superfines and photo papers.

I speaks of the rust scale on steel bars coming off and rendering them unsuitable for fine paper.

K will find, if he makes inquiries, that his first remarks are not correct, namely, that up to, say, 1895 steel bars were in general use and fulfilled all the requirements of the paper-maker. Brass bars have been in extensive use for many years. His remarks about "brass bars retaining a sharp cutting edge until quite worn down" is what I have been looking for in other papers. The edge, of course, is square instead of rounded, and therefore always retains a certain amount of cutting power. The following statement is worth the attention of practical paper-makers, "a combination of the qualities of cutting and beating is

generally aimed at, and this we find when the leading bars of each bunch are of brass, all the rest being steel."

L. The instance of phosphor bronze bars being taken out after ten loadings and superseded by steel ones cannot be taken for the purpose of drawing general conclusions of the relative merits of brass and steel, as it is exceptional.

M goes into the question of the number of years steel bars will last, and states they have to be taken out and hammered after the first eighteen months, and compares this with the wear on bronze bars. He then gives the comparative cost of the two and sums up in favour of bronze bars. I should like to point out, however, that circumstances alter cases. It is not very often that bronze bars will last six years without repair. It would depend upon the class of beating required.

N. Bronze bars do not break so much as steel. Steel bars vary in temper, being decidedly harder in some places than others. These are reasons in favour of bronze not mentioned by previous students.

R.—"For esparto fibres I would prefer steel bars, as this fibre does not require the drastic treatment usually given to rag fibre." He goes into the question of rusting when allowed to stand from Saturday till Monday, and gives the relative first cost of steel and bronze bars.

S.—"It is a good plan to give the new steel bars a coat of varnish." The idea of coating them with something that will prevent rust is a good one and has been tried. The difficulty, I believe, is that any enamel, etc., is liable to chip, and the rusting takes place on the edge that comes in contact with the bed-plate and in time undermines the enamel.

U speaks of the improvement made in the composition of brass bars, and states that "they are now made so tough as to wear even better than steel bars." In none of the answers is there anything said about small shavings of brass coming away from time to time and finding their way into the paper.

CHAPTER II.

SIZE AND SPEED OF BEATER ROLLS.

Speed—Revolutions—Arrangement of bars—Diameter—Definition of terms.

QUESTION 2.—*What speed (in revolutions per minute) do you recommend for a Hollander beater roll? Does the size of the roll, and the number and arrangement of the bars, affect the question?*

B makes one unfortunate, although perhaps natural, mistake. "The speed of cutting is directly proportional to the outside diameter of roll." In my opinion the speed of cutting, roughly speaking, varies as the square of the outside diameter. Therefore, if the diameter be doubled the speed of cutting is quadrupled, not doubled. He shows the influence of placing the bars in clumps in comparison to placing them equidistant from one another, and gives data for calculating the number of feet per minute that the bars travel, and also the number of cuts they make per minute, but has omitted to square the diameter.

D gives a very low number of revolutions per minute, unless he is referring to a big roll, which he does not state. His remark about putting the bars too close, causing the space between the bars to block up, and so preventing the travel of the stuff, is certainly a point which materially affects the question.

E points out the necessity for having a certain travel of so many feet per minute, but does not point out how the diameter of the roll would effect this.

F gives a very fair answer. He shows that the bars being in clumps assists the circulation, each clump acting as a paddle, and also shows that clumps are unnecessary with beaters provided with more modern means of circulation. The speed which he gives for a roll of given dimensions is very much to the point.

G recommends a surface speed of 2000 feet per minute,

making not less than 200,000 cuts. His answer shows that he knows how to tackle the question, but he does not show how the arrangement of the bars might affect the question.

I is quite right in supposing that a uniform number of cuts per minute is to be aimed at. He states that the speed depends upon the class of paper to be dealt with, which is quite right. He, in common with one or two others, states that the bars in clumps should be close together. This helps to make the roll run evenly. This is a good practical remark.

J in a few words gives the essence of the question, but he ends up by saying that the number and arrangement of the bars makes no difference to speed. This question is largely dealt with in Hofmann's treatise relating to beaters. Number and arrangement of bars does materially affect speed, the reasons for which space will not allow us to go into here.

M gives the best answer to this question. He realizes that the action of the rolls is like that of a paddle in promoting circulation, and that sufficient space is needed between the clumps for the stuff to get between. If these spaces are diminished the circulation is impeded.

Q states that "the greater the number of bars the larger the roll must be to get the stuff ready in the same time as with a smaller roll with smaller number of bars." Undoubtedly this is the case, but the question is also to a large extent affected by the speed. It does not appear to have occurred to most of the students that the speed, the diameter of the roll, and the number of fly-bars, and bars on the bed-plate, when multiplied together, will give an expression for a definite amount of cutting or beating power per hour. Supposing that you have a beater of 4 cwt. capacity dry weight, and the beating takes four hours, it is a matter of fairly simple calculation to determine the diameter of a roll for a 2-cwt. beater when the number of revolutions, the number of fly-bars, and bars on the bed-plate, etc., are known.

Stress has already been laid upon the fact, that the number of bars is an important factor. The arrangement of bars, namely, the number in each clump and the distance between the clumps, materially affects the circulation. The circulation is promoted by the lifting capacity of the roll, which is dependent upon the distance between the clumps as well as the distance to which the clumps project from the roll. A certain amount of circulation, neither too great nor too little, is required in the beating. Sufficient, for instance, to cause the stuff to travel once round the engine in three minutes. It is easy enough to see that both the

number and arrangement of the bars would have a great deal to do with this, but space will not allow of further discussion of this subject here. Some knowledge of it can be got by reading those chapters in Hofmann's dealing with beating.*

S gives a specific instance: "About 200 revolutions per minute; diameter of roll $2\frac{1}{2}$ feet; 500 lb. beater;" and then says, as size of roll increases revolutions per minute decrease. This is short, but to the point.

T gives a specific instance, and also mentions the number of bars, but the latter part of his answer is quite wrong. He concludes that the size of the roll does not much affect the question, as a larger roll means a larger engine with more stuff. I would remind him that the great thing to be aimed at is a certain surface speed. It is true the capacity increases with a larger roll, but nothing like the extent to which the cutting power of the larger roll does. Roughly speaking, the cutting power of a roll varies as the square of its diameter. Roughly speaking, a beater varies directly in proportion to its width. This would be true if all beaters were of one depth, but the larger ones are somewhat deeper than the smaller ones, although not in proportion to their width.

The power consumed per cwt. of stuff beaten decreases in proportion as the capacity of beater increases. This has been proved by actual experiments, the details of which are given in "The Theory and Practice of Beating."

U goes into the question of the influence of the weight of the roll upon the beating. I can see the point he is aiming at, but he has not expressed it quite clearly. It would be best to say, I think, that a heavy roll can be made to draw out the stuff best, as it can be made to revolve in close proximity to the bed-plate without lifting or being lifted by the stuff. A lighter roll has to be let down in closer contact to exert any influence, and by so doing is liable to cut the stuff too much, but you must not lead one to infer that a heavy roll cannot be made to cut the stuff as easily as a light one.

V gives very much the same sort of answer in regard to the influence of the weight of the roll. His remark, "The large roll being the strong feature of a Hollander," requires qualification. Large in comparison with what, and for what particular purpose is the large roll beneficial? The class of beating affects all these questions.

* Hofmann's "Treatise on Paper-Making." London: Sampson Low, Marston & Co., Ltd.

My statement that, "roughly speaking, the cutting power of a roll varies as the square of the diameter," I would urge is a justifiable remark, but before attempting to prove this, I must define a few terms coined for the purpose of my arguments.

Cutting area of roll = area of roll traversed by fly-bars = circumference × length of roll.

Cutting length of fly-bars = number of bars × length of roll.

Since the circumference of a roll bears a direct ratio to the diameter (3·1416 : 1), the so-called cutting area of rolls of uniform width are in direct proportion to the diameter.

Let circumference = C. Diameter = D.

Distance between centres of clumps = d.

No. of bars per clump = a.

Length of roll = L.

Supposing the diameter D is known, and we require the cutting area.

$$\text{Cutting area} = D \times 3{\cdot}1416 \times L$$

$$\text{Cutting length of fly-bar} = \frac{D \times 3{\cdot}1416 \times L \times a}{d}$$

But the "cutting power" must be regarded as something distinct from the "cutting area" of a roll. Power can be expressed in foot-pounds. The "cutting power" of a roll may be regarded as a function both of the cutting length of the fly-bars and of the weight of the roll.

Provided rolls are solid, the weight of rolls of uniform length will vary as the square of their diameters.

The weight of a solid roll of any material, such as cast iron, can be arrived at by multiplying its cubical contents by its specific gravity.

The cubical contents equal $D^2 \times 0{\cdot}7854 \times L$. With a roll 4 ft. diameter by 4 ft. in length we should have—

$$4 \times 4 \times 0{\cdot}7854 \times 4 = 50{\cdot}26 \text{ cubic feet.}$$

One cubic foot of cast iron equals 450 lbs. Therefore the roll in question would weigh 50·26 × 450 = 22,617 lbs., or about 10 tons. A roll of this size, however, in consequence of its being made hollow, weighs about 4 tons. If it were made solid it would be far too heavy for the work it has to do. In practice, I think I am fairly right in saying that the beating power of rolls vary as the square of their diameters, or nearly so. I will take a practical instance to test the validity of this statement. Beveridge, in his "Pocket-Book," gives the dimensions of

Umpherston beaters. An Umpherston of 2-cwt. capacity would require a roll of 2 ft. 6 in. diameter and 3 ft. long. The table shows a large Umpherston with a roll of 3 ft. 6 in. diameter by 4 ft. 6 in. long. What would be the capacity of the latter beater on my assumption that the beating power of the roll varies as the square of its diameter? We must, for the moment, assume that the beating power of all sizes is in proportion to their relative capacities of dry stuff, which is only another way of saying that all sizes will do the beating in an equal length of time.

$$2 \text{ ft. } 6 \text{ in.} : 3 \text{ ft. } 6 \text{ in.} :: 5 : 7.$$
$$3 \times 5^2 = 75.$$
$$4 \text{ ft. } 6 \text{ in.} \times 7^2 = 220{\cdot}5.$$
$$75 : 220{\cdot}5 :: 1 : 2{\cdot}94.$$

As the 2 ft. 6 in. diameter roll is required for a 2-cwt. beater, the 3 ft. 6 in. diameter roll should suffice for a beater containing 2 × 2·94, or 5·88 cwts., or 658 lbs.

Now, this size roll (*i.e.* 3 ft. 6 in. diameter × 4 ft. 6 in.) is used for a 6-cwt. beater, which is within 14 lbs. of my figure, on the basis that the cutting power varies as the square of the diameter. It may be only a coincidence that the diameter, length, and weight are so adjusted as to work in this manner, but, nevertheless, it is a fact.

The cutting area of roll and cutting length of bars vary, roughly speaking, directly as the diameter, but the roll, as it increases in size, also increases in weight, and, as weight is a factor in calculating cutting power, the question is somewhat complicated. As already shown above, the cutting power of a roll in practice does not vary as the diameter of roll, but the variation approximates nearly to the square of diameter of the roll. It must be assumed, of course, that the speed of the fly-bars is the same in each case, and also the number of knives in the bed-plate, etc.

The total cutting length of a beater roll may also be arrived at by multiplying the number of fly-bars by the length of roll; and the cutting length of bed-plate may be arrived at by a similar process, expressing the cutting length in each case in feet.

In order to determine the "available effective cutting" of a beater, the cutting length of the fly-bars must be multiplied by the number of knives in the bed-plate, and this figure must be multiplied by the number of revolutions of roll per minute.

This last figure, when multiplied by the weight of roll in

pounds, will give some expression of the cutting power of the beater for rough purposes of comparison, *at any one speed of fly-bars.*

Thus with a roll 4 ft. diameter by 4 ft. long, carrying 100 bars, the cutting length would be $100 \times 4 = 400$ ft. The bed-plate for same carrying 24 bars, 4 ft. long, the cutting length of bed-plate would be $24 \times 4 = 96$ ft.

If the roll made 150 ft. revolutions per minute, the "available effective cutting" (not cutting power) would be—

$$100 \times 24 \times 4 \times 150 = 1{,}440{,}000 \text{ ft., minute, cuts.}$$

Now, supposing we had two rolls possessing equal "available effective cutting," and in all respects the same as to diameter, speed, etc., except weight, the heavier roll would have the greater cutting power. For this reason, years ago, when Hollanders were provided only with solid wooden rolls, the cutting action was necessarily slow, independent of the size of roll, number of bars, etc., because the weight was insufficient.

CHAPTER III.

THE FADING OF PRUSSIAN BLUE PAPERS.

Prussian blue—Its use in paper pulp—Liability of fading—Conditions affecting stability—Chevreul's researches.

QUESTION 3.—*What do you think of Prussian blue for colouring paper? What paper would you use it for? Under what conditions do Prussian blue papers fade?*

B.—Prussian blue has the advantage over ultramarine in that it will withstand acid, but disadvantage in that it is destroyed by alkali.

C.—Prussian blue mixed with yellow may be used for making a green paper.

E.—Prussian blue is good for colouring tints. Being affected by alkali, it is better not to add Prussian blue until sizing is complete. One student says that chlorine in the pulp destroys Prussian blue, and another says that it is not affected by it. These two opposite conclusions are no doubt due to the fact that chlorine or hypochlorites do brighten up the colour by oxidation, but that if an alkaline reaction is left behind due to free CaO in the bleaching powder after the chlorine is neutralised, this free lime would tend to discharge the Prussian blue.

G goes into the question of Prussian blue gravitating to underside of the paper in consequence of its high specific gravity, causing one side to be darker than the other. He must remember that this is true also of ultramarine, and other pigments. This question is influenced largely by the way the paper is made on the machine, and how the blue is prepared.

H recommends Prussian blue for papers of a green shade.

L knows something about colouring papers, but his experience differs from the others on the question of fading. As he uses

Prussian blue in conjunction with ultramarine, the fading might not be so apparent as when Prussian blue is used alone. His experience of its fading is confined to papers left standing about in damp places for a long time.

R's final sentence, "For other than cheap papers in which a lasting shade is not essential, it would not appear suitable," should be noticed by others.

S's few remarks are correct. "Used mostly for colouring heavy-dyed papers;" "Has a greenish tint, and is used with chrome yellow to form a green paper;" "Also used for blue papers."

T's statement that "Prussian blue is a good strong colour" is true if the colour is added in a way to get the most benefit from it. A small weight of material can be made to colour a lot of stock, especially if the chemicals are added so as to precipitate the blue in the pulp itself. "I would use it principally for commoner shop papers" is a very fair statement.

U's remark that a much deeper blue is obtained if any free acid is present, is true. The exact state of the pulp in this respect affects the quality of the colour to a considerable extent. "Prussian blue papers fade on long exposure to sunlight, prussic acid being evolved. The colour, however, is restored by keeping in the dark for some time." This is a remark I had hoped to see in other papers. Compare this with my remarks on page 20.

V.—It is a mistake to suppose that free acid is an advantage as a permanency. It is all right to set and develop the colour in the pulp. There is practical truth in the remark that "It cannot be used in the manufacture of wall-papers, as the lime on the walls would destroy the colours, forming oxide of iron."

N.—The question of fixing the colour is rather dependent on whether the blue is added in the form of a "paste," or whether the ferric salt is added to the pulp and then the potassium ferrocyanide. Sizing might help to fix the colour, and every trace of alkalinity must be removed by having sufficient alum present. Alum is of more value for this purpose than for "stopping the bleeding." Undoubtedly having the stuff well beaten and working "wet," helps the fixation of colour, but it is necessary to think of the *kind* of paper to be produced, and other things have to give way to this.

The following paragraph from a publication of mine will, I hope, help to a better understanding of the behaviour of Prussian blue in paper. From this, the reader will get some idea of what the author had in mind when he set the question. It should, furthermore, be of some practical value in everyday work :—

Prussian blue, on account of its instability and want of refinement in tone, is generally only made use of in the commoner classes of paper.

The blue obtained by simply passing cotton dyed with iron-buff, through a cold acidulated solution of potassium ferro-cyanide is extremely fast to light, but is readily decomposed in alkaline solution. As has been previously pointed out, the blue is here formed *in situ*, and is found under these conditions to be much more permanent.

Paper pulp can be dyed with Prussian blue by adding a ferric salt, and then potassium ferro-cyanide in molecular proportions, and if necessary, a little bleaching powder solution previously acidified by passing carbonic acid gas through it.

The blue, in this case, can only be partially formed *in situ*, and is therefore not so permanent as the previous preparation. The extent of its permanence is dependent upon the power of attraction that the cellulose exerts for the ferric salt, and this varies considerably with the character of the cellulose constituting the pulp. The ferric salt is partly condensed, the rest remaining in solution. That which attempts to pass into the cell-wall is dissociated into ferric hydrate and free acid. In the case of a ferric salt passing through a dialysing medium such as a cell-wall, dissociation only takes place so far as the acidic portion penetrates while the basic portion remains behind. In other words, the iron would not penetrate the fibre, but the acid with which it was combined, leaving ferric hydroxide as an insoluble coating. A ferrous salt can be used in place of a ferric salt, in which case the pulp must have a final treatment with an oxidizing agent such as bleaching powder. When the potassium ferro-cyanide is added, the blue is partly formed within the fibre and partly as a precipitate, which is retained by the fibre.

The most usual way, however, is to apply the blue paste to the pulp after mixing it in water.

Colours are said to be "fast" when they fade very slowly or not at all, and fugitive when they fade rapidly. Some colours are faster than others. The rapidity with which a colour fades depends not only upon the nature of the colour itself, but also upon the nature of the material dyed with that colour; also upon the atmospheric conditions. This matter has been exhaustively studied by Russell and Abney, and the following are the conclusions they came to, expressed in their own words: "The presence of moisture and oxygen are in most cases essential for a change to be effected, even in the vegetable colours. The exclusion of moisture and

oxygen, particularly when the latter is in active condition, would give a much longer life even to these than they enjoy when freely exposed to the atmosphere of a room. *It may be said that every pigment is permanent when exposed to light in vacuo, and this indicates the direction in which experiments should be made for the preservation of water-colour drawings.*

"The effect of light on a mixture of colours which have no direct chemical action on one another is that the unstable colour disappears and leaves the stable colour unaltered appreciably. Our experiments also show that the rays that produce the greatest change in a pigment are the blue and violet components of white light, and are present in comparatively small proportions in artificial lights usually employed in lighting a room or gallery."

The primary atmospheric factors which cause colours to fade appear to be moisture, air, and light. Neither of these will act alone, nor will any two without the third.

From this, then, we would conclude that no fading action could take place when light is excluded, as in the night. This, however, is not true. When the sun is shining, the rays of light convert the comparatively inert oxygen contained in the atmosphere into ozone. This substance is oxygen condensed to two-thirds its former volume, and is in a highly active condition: $3O_2 = 2O_3$. (Three molecules of oxygen = 2 molecules of ozone.)

Ozone is such an extremely active substance that if formed under ordinary circumstances when the sun is shining would rapidly react with any organic substance in the neighbourhood, and would remain but a very short time undecomposed.

Another highly active substance is formed through the intervention of moisture, which is known as hydrogen-peroxide: $2H_2O + O_2 = 2H_2O_2$. (Water and oxygen = hydrogen-peroxide.) This substance has a great bleaching action on animal and vegetable colouring matters. It gives up half its oxygen, which being in its nascent or active state, readily oxidizes any colouring matter, and forms water, thus reversing the action of the sun's rays.

To what extent the sun's rays are directly responsible for the formation of ozone and hydrogen-peroxide, and to what extent they are indirectly responsible by setting up electrification, due to condensation and evaporation, need not be considered. We may take it that the sun is primarily responsible for the formation of these two substances, to whose presence in the atmosphere we are partly indebted for the unsatisfactory changes that take place in many coloured papers. Captain Abney suggests the probability

of colours fading much more rapidly in seaside places than inland, due to the presence of much more ozone in the atmosphere.

*Chevreul found that Prussian blue behaves abnormally—it even faded in vacuo, and the strangest thing of all, on keeping the faded colour in the dark and exposed to air the colour returned again. He explains this by supposing that it lost cyanogen, or hydrocyanic acid, in vacuo in the light, and in the dark, exposed to air, it absorbed oxygen, and concludes that the fading is due to reduction.**

We must bear in mind that observations made with water-colours spread on paper are not coincident with those made upon the same colours when used to colour papers during their manufacture. The former is only a superficial coating; the latter is considered by some to react with the cellulose, of which the paper is composed. Nine-tenths or more of the water-colours are applied to paper containing nothing but cotton and linen, whereas tinted papers are mostly composed of other celluloses, some of which react very differently with most of the colours used. Prussian blue is peculiarly susceptible to external influences. If the conditions are such as maintain the colour, it is said to be fast; but if the conditions are such as to bring about some chemical change, such as that cited above, the colour is discharged. Unlike most colouring matters, when these conditions are reversed the colour is again restored.

It happens sometimes that papers containing Prussian blue behave just opposite to Chevreul's paper in vacuo. The colour is found to be discharged in the dark, and to be less acted on in the light. The paper when stocked is, of course, only exposed to the rays of light at the edges, the centre being left in darkness. The difference between this case and that of Chevreul's is that Chevreul's paper was removed from the action of the atmosphere by placing it in a vacuum when in the light, but the air was allowed free access in the dark. In the case of the bale of paper, or in a book with the edges exposed, the air is allowed free access to the edges at the same time that the light is acting upon it. Where it is packed close together, both air and light are excluded. If then, as Chevreul concludes, the fading is a process of reduction, we might well guess that paper packed tight together in the dark,

* Possibly Chevreul's explanation would not be accepted at the present day. I doubt if the composition of Prussian blue was rightly understood in his time, and it is difficult to see how a loss of colour due to cyanogen would be remedied by the absorption of oxygen. Many colour changes brought about by the action of light on organic substances have been shown to take place without any change in composition, the change in one case I have in mind is reversed on shutting out the light.—Dr. H. P. Stevens.

and excluded from the oxidizing influences of the atmosphere, is as likely, if not more likely to fade, than the same when placed in a tube in vacuo in direct sunlight.

The reversal of these conditions undoes the deoxidizing due to the exclusion of oxidizing influences, and the colour is more or less restored.

If these views are correct, it would appear, then, that Prussian blue papers have a natural tendency to fade, but that the colour is maintained by the oxidizing constituents of the atmosphere—ozone, hydrogen-peroxide, and perhaps oxygen—which, when present in sufficient quantity, will not allow of reduction. In this respect, then, Prussian blue differs from other colours. The above remarks will, I trust, be found of use to papermakers, who use considerable quantities of Prussian blue in their papers.

CHAPTER IV.

THE EFFECT OF LOWERING THE BREAST ROLL.

Its effect in making paper illustrated by hand-mould—Eibel's process.

QUESTION 4.—*Can you easily demonstrate, by means of a hand mould, the effect of lowering the breast roll? Explain why a slight lowering of the breast roll will have so much effect upon the removal of water.*

B shows that it can be demonstrated by inclining the mould and giving it a forward motion. He shows a similarity between this action and the behaviour of the stuff on the machine.

C.—"By canting it up the water will fall out more easily." His few words on the subject are very good.

E points out that lowering would require more water to carry it over the wire, and consequently if it were heightened it would require less. This is true, but it does not clear up the question. He has rather mixed up cause and effect. He will notice on reading the question that the lowering the breast-roll is the cause, and I have asked what the effect would be.

F says there is not such a rush under the slices and the pulp has to run uphill. The pulp comes on to the wire from the apron more steadily, and consequently the water leaves it more readily. He shows that he knows what he is talking about, but he does not bear in mind my question sufficiently. I do not think it can be claimed to any extent that the rush of the water prevents it getting through. The main cause is something else.

G, in remarking that the tendency of the water is against the run of the wire, makes a true statement, but does not throw much light on the question of the removal of water by lowering the breast-roll; in fact, it might lead us to assume that it would have a retarding action.

H.—Lowering the breast-roll allows more time for the water to get through the meshes of the wire.

I.—The production of "A small dam of liquid tapering up to the suction boxes" is a good way of describing its effect. He makes his argument clearer by speaking of the raising the breast-roll, causing the stuff to pass along more quickly, thus leaving less time for the water to drain away.

J.—"A good well of water and stuff is formed just where the action of the shake will have the most effect in lacing it together." This is a good practical remark.

R.—"The fibres being held longer in suspension are more thoroughly felted together." This is true, but what effect, if any, would the felting have upon the removal of water? He is quite right in saying that it would appear that not much attention is given to the matter when there is not a wide difference in substances. Certainly some mills do not trouble about raising and lowering the breast-roll at all.

S takes a different view. "The lowering of the breast-roll is one of the principal things in the making of a paper at the machine." So it is in some instances.

V shows the effect of holding a hand-mould in an inclined position, and draws a distinction between the top end and the bottom end. This simile is a good one. I do not think increased capillary action has anything to do with the matter, but pressure undoubtedly has. As a consequence, more water is taken out in a given time.

Lowering the breast-roll increases the depth of the water at the end of the wire, thus increasing the pressure and consequently the rate of flow through the wire.

If a hand-mould is held horizontally whilst being shaken, and the deckel subsequently removed, you will notice that the drips fall slowly, but if the mould is inclined cornerwise a ready flow of water will be noticed from the lowest corner. This is not the result of pressure, but the effect of water running down an inclined plane along the under surface of the wire, etc. Water does not readily leave the under surface of a wire as long as it is exactly horizontal, the drips coming away with difficulty, but immediately it is inclined the flow becomes brisk, not by dripping from all over the surface, but by coursing down along the under surface. One must regard the water on the under surface as a stream which cannot be made to flow until there is a difference of levels, occasioned either by lowering the breast-roll in the case of machine-made, or inclining the mould in the case of hand-made papers.

CHAPTER V.

THE EFFECT OF "LOADING" ON THE TRANSPARENCY OF PAPERS.

Its effect on Opacity—Transparency—Substance—Weight and other qualities.

Question 5.—*Why does loading make some papers more opaque than others? Give instances.*

B states that the paper containing the most loading is the most opaque. The question should not be dealt with in this way. Let us assume half a dozen papers of different furnishes, but each containing, say, 10 per cent. of the same loading, such as clay, and half a dozen papers corresponding with the above in every respect, *e.g.*, furnish, thickness, etc., but without the addition of clay. Why does this self-same 10 per cent. of loading render some more opaque than others, or why does this loading add more to the opacity of some papers than others? It is not a question of one paper retaining more than the other, as one has to assume that each paper, for the sake of comparison, has the same proportion of a given loading in it.

E throws more light on the subject. It is impossible to judge from his answer, however, whether not bleaching the stuff so much renders it more or less opaque, but he certainly scores a point here, because bleaching *does* materially influence the result.

F says that clay is more opaque than the fibres. This is a good remark to begin with, but he goes wrong, like many of the others, in discussing the probable effect of the stuff working wet or free upon the retention of the mineral. This is not a part of the question. "Should the stuff be beaten fast the water leaves it quicker and the loading will not be retained; the paper will be transparent." He is very much at sea here, as will be explained later.

G gives useful information but no proper answer to the question. "Mineral is retained better in stuff that works wet on the machine than stuff that works free." To have stated the difference in opacity between a paper made from free stuff containing 10 per cent. of clay as compared with the same free stuff without clay and a paper of the same furnish, but from wet stuff containing 10 per cent. of clay as compared with the same fibres without the clay, would have furnished a specific case in point. We should here have a direct measure of the influence of a given amount of clay upon two papers of different opacity.

H.—"The wetter the stuff the better it carries the loading," which loading renders it more opaque. The statement is correct, but it leads one to infer that the loading adds more to its opacity because it contains more mineral.

I.—"With a paper which has the fibres long, loading does not make it opaque, but with a paper made of fine stuff loading makes it opaque." This is rather vague. I think you will find it is something more than a question of the fibres being short or long. It is probably more a question of time of beating and whether the fibres are wet or free. In order to avoid confusion, one kind of loading should be dealt with at a time. It does not matter which loading is taken, so long as it is capable of demonstrating the views expressed.

L thinks that by closing the pores it would have the opposite effect. Although he is quite wrong we must give him credit for exercising his reasoning faculties. If one could completely fill the pores of a paper with a substance like wax, it would be possible to render a paper transparent, and rosin sizing may help to do this. But a substance such as wax is, by itself, transparent, whereas a substance like clay, even in the thinnest coat, is opaque. If the whole of the pores of a paper were filled with clay (which, however, is not possible in practice) the paper could not become transparent as when treated with wax, but intensely opaque.

M.—"The addition of clay to a well-milled linen rag paper will make a greater difference to its opacity than adding clay to an esparto paper, because the former being much more pure and transparent than the latter, the addition of clay will make a greater difference." This is the sort of remark I have been looking for. Given two fibres, the one producing a more transparent paper than the other, an equal weight of some opaque substance, such as clay, mixed with each in an equal proportion, by weight, will exercise different effects in the two cases. The more

transparent fibre will, of course, be affected in a greater degree than the more opaque one.

N.—The effect of loading in increasing the opacity increases with the purity of the fibre. What is understood by purity? Nothing could be purer than a filter paper, but it is opaque, whereas a linen bank, which perhaps is nothing like so pure from a chemical point of view, is transparent. The word "purity" does not apply here. It is evident that by purity is meant some particular quality, as, for instance, the absence of incrusting matter, but it is necessary to be more particular in the choice of terms. The instance given of stuff being drawn to the under side of the sheet and blocking the pores on one surface is a good one.

R shows that he has a better understanding of the question. "Why do two papers of equal residue have different characteristics as regards opacity?" He gives correct instances in answer to this question, and he reasons the thing out well. Stuff working wet certainly does retain mineral more readily than stuff that works free, but this does not afford an answer to my question. Stuff that works out wet is influenced more by the presence of clay than free stuff, because the wet stuff alone would produce a more transparent paper, and, therefore, an opaque substance like clay would exert a greater influence upon it than upon the comparatively opaque free stuff. A loaded paper is certainly more opaque than an unloaded one, as is evidenced by an imitation art paper, which generally carries from 15 to 20 per cent. more clay than an ordinary printing. Litho papers also possess this characteristic.

V says: "If the stuff is beaten wet, the fibres have been milled and flattened out, and the reflection in the inside of fibre and on its surface is less, consequently it looks more opaque or deadened." This leads one to conclude that he does not fully understand what opacity means. The opacity of a paper is judged by looking *through*, not *at* it. Some may regard this statement as unintelligible, because if a paper be thrown down upon a table and looked at from any part of the room, if in a good light, a keen observer may form some idea of its transparency. Although he looks *at* it he is nevertheless unconsciously looking partially *through* it. Opacity is the reverse quality to transparency. The less one can see through a paper the less transparent and the more opaque it is. If, as **V** rightly concludes, the wet stuff reflects the light less, it transmits the light more, and consequently it is more transparent and not more opaque. A so-called "deadened" look is more likely to be the result of increased transparency than an

increased opacity. If by increased deadened look one *infers* greater transparency, then it may be said that the transparency is or can be judged by looking *at* a paper, but the inference is not always justifiable. Take a pure filter or blotting paper, which are made of very free stuff, and look at it, you will notice that it looks the very reverse of "deadened." Look through it by holding it to the light and you will see that it is opaque. You will, however, find the inverse qualities in many papers made from wet stuff. The power of reflecting light is a measure of opacity, and that of transmitting light a measure of transparency. This brings us to the essence of the whole question. Pure cellulose, if it were not for its physical structure in the form of fibres, would be as transparent as a sheet of glass or as a sheet of ice. On account, however, of its fibrous structure the light is dispersed, giving to the eye the impression of whiteness. As the condition approaches that of amorphous cellulose, the sheet becomes more transparent. In highly glazed papers this is particularly noticeable. As a simile attention might be drawn to ordinary ice which is perfectly clear, but when in the form of minute crystals such as snow, it appears to be pure white and opaque on account of its power of dispersing the light in all directions. As a matter of fact individual crystals of ice are transparent, and so are individual fibres of pure cellulose such as cotton.

CHAPTER VI.

TERRA ALBA AS A LOADING FOR PAPER.

Calculations for solubility—Loss—Composition of backwater—Ash in paper.

QUESTION 6.—*A "furnish" for writings contains* 100 *lbs. of commercial terra alba per* 400 *lbs. of dry fibre. A small sample of the terra alba in question, when burnt, will be found to yield* 55 *per cent. of ash. The stuff is diluted in chest with* 23 *parts of water for every part of dry fibre. The web, as it passes on to the drying cylinders, consists of* 28 *per cent. dry material and* 72 *per cent. of water (for purpose of calculation, we must assume no loss through leakage, etc., or dilution of back-water, other than that necessary to make up for moisture in web of paper). After a run of* 5 *tons of paper (total weight at cutter), the machine is shut down and the terra alba found collected on sand tables and in saveall, etc., weighs* 320 *lbs. An average sample of this, on burning, is found to yield* 35 *per cent. of ash. What ash would you expect to find in the finished paper? Show details of calculation, and where losses occur and how.*

One answer was so excellent that it was decided to publish it, and to ask the author whether he would agree to have his name made public. Mr. Andrew Gray is the gentleman in question.

The answer is as follows :—

Furnish—

400	lbs.	fibre.
100	,,	terra alba.
9,200	,,	water.
9,700	lbs.	

Percentage of composition of 9,700 lbs. :—

Fibre	4·12	} 5·15 fibrous material.
Terra alba ...	1·03	
Water	94·84	
	99·99	

Proportionate part of water and fibrous material :—

$\frac{94{\cdot}84}{5{\cdot}15}$ = 1 part fibrous material = 18·41 parts water, as it would appear in the chest.

Paper as leaving press rolls contains 28 per cent. fibrous material and 72 per cent. water = $\frac{72}{28}$ = 1 part paper = 2·57 water.

Taking cent. per cent., we had a loss of 15·84 parts between chest and cylinder, which would represent back-water, part of which would be continually bringing the stuff forward to machine. Consequently, on a making of 5 tons of paper, we would have to account for—

5 tons × 15·84 = 79·20 tons of water × 2,240 = 176,408 lbs.

The 5 tons of paper leaving press rolls contained 28 per cent. fibre and 72 per cent. water, the proportion being 28 to 72 = 1 ton to 2·57. 2·57 × 5 = 12·85 ton × 2,240 = 28,784 lbs. of water evaporated on machine cylinders, so the total quantity of water used in making the 5 tons of paper would be :—

	lbs.
As back-water	176,408
Evaporated on cylinders	28,784
	205,192

We used in our furnish terra alba, which is soluble to the extent of 0·022 lbs. per gallon. Quantity of water used in making = 20,519·2 gallons. 20,519·2 × 0·022 = 451·42 lbs. dissolved in the water. Of that quantity, however, the amount carried forward by the water in the pulp and which is evaporated on the cylinders would be retained in the paper, as the residue would be left in the pulp, so 2,878·4 gallons × 0·022 = 63·32. So we actually lost in solution 451·42 − 63·32 = 388·10. The back-water generally carries along with it fine divided fibrous matter and mineral in suspension, amounting from 7 to 9 parts per 10,000. Taking an average of 8, we would have carried in suspension in the water

$\frac{176{,}408 \times 8}{10{,}000} = 141{\cdot}12$ lbs. This, on analysis, shows that it contains 60 per cent. mineral and 40 per cent. fibre, so we would have in 141·12 lbs.—

60 per cent. = 84·67 terra alba.
40 „ = 56·45 fibre.

On sand tables, etc., we collected 320 lbs. terra alba, which on ignition contains 35 per cent. mineral residue, but the terra alba used in the furnish represents 55 per cent. on ignition ; therefore it could not all have been terra alba. The difference probably would be water and fibre, but as terra alba only is mentioned we will assume it is water. The value of this collection as compared with the terra alba in furnish would be 55 : 35 :: 100 = $\frac{35 \times 100}{55} = 63{\cdot}62 = \frac{63{\cdot}62 \times 320}{100} = 203{\cdot}58$ lbs. = Difference 116·42 lbs. water.

Let us now look at what we actually have got :—

		lbs.
Terra alba lost in solution	... ...	388·10
„ „ „ suspension	... ...	84·60
„ „ „ sand tables, etc.	...	203·58
		676·28

Fibre lost in suspension ... ... 56·45 lbs.

		lbs.
Paper made	... ...	11,200·00
Fibre lost in suspension	... ...	56·45
Terra alba lost	... ...	676·28
		11,932·73

total quantity of stuff as put into beater. This stuff contains fibre and mineral in the proportion of 80 per cent. fibre and 20 per cent. mineral—

			lbs.	
11,932·73 lbs.	fibre	... ...	9,546·24	= 80 per cent.
	terra alba	...	2,386·56	= 20 „
			11,932·80	

	lbs.
Fibre 9,546·24 lbs. – 56·00 lbs. fibre lost	= 9,490·24
Fibre as paper = 84·73 per cent.	
Terra alba, 2,386·56 lbs. – 676·28 lbs. terra alba lost	= 1,710·28
Terra alba as paper = 85·26 per cent.	
	11,200·52

but as 100 parts of commercial terra alba only shows 55 parts of ignited residue, the ignited residue as found in the paper would be $\frac{15 \cdot 26 \times 55}{100} = 8 \cdot 37$ per cent. The losses, as I have stated, would be: in back-water, terra alba and fibre; in solution in water, terra alba only; on sand tables, etc., terra alba only.

Author's Comments.

Instead of giving a full answer myself, it will be, perhaps, more instructive if I make certain comments on the above answer. The amount of "furnish" given is right, and also the proportion of water, calculated from the ratio of "fibre" and "water" given in question. The so-called "fibrous material," 5·15 per cent. made up of fibre and moist terra alba, the balance of course represents the per cent. of water. In working out this percentage, many would have gone wrong. The proportionate part of fibre-material is also correctly stated. Mr. Gray has very ingeniously avoided most of the pitfalls in this answer, but he has, however, fallen into one very unfortunate pitfall; had he not done so, he would probably have had very nearly full marks. When you ignite terra alba, the dry weight consists of $CaSO_4$, but to arrive at the percentage of the dry crystallized terra alba, it is necessary to calculate $CaSO_4$ into $CaSO_4 + 2H_2O$, and the difference between the latter percentage and 100 represents the actual amount of moisture in the sample. Mr. Gray goes the right way to work in calculating the ratio of water to dry fibrous material, and then multiplies the figure by five tons to arrive at the weight of water contained in the chest.

He makes a slight error in calculating the total amount of water. The figures should be 177,408 lbs., not 176,408 lbs. He is right in going the same way to work in arriving at the ratio of water to dry fibre carried forward from the press rolls, and in multiplying this by 5 tons, and the number of pounds per ton, to arrive at the actual weight of water evaporated over machine

cylinders. The difference between this and the original total amount of water, of course, gives the net amount of water actually disappearing. Now we come to the point which, certainly, nine students out of ten would have lost sight of, and that is the solubility of terra alba in water. Mr. Gray takes the total amount of water which goes to waste as above, and knowing the number of pounds per gallon which the water dissolves, he arrives correctly at the number of pounds of terra alba which actually disappears by the solubility in water. The solubility of terra alba in water is dependent upon the temperature—at freezing point one gallon would dissolve 0·0205 of the dry crystalline substance; at 95° Fahr. one gallon dissolves 0·0254. Mr. Gray's figures of 0·022 lbs. per gallon for the ordinary temperature of the chest is correct; his slight mistake in his calculation in the volume of the back-water, of course, produces a slight error through his calculations. He has gone rather a roundabout way to arrive at the amount of terra alba lost from dissolving in the water. It would have been better to have deducted the volume of water evaporated at the drying cylinders from the total volume of water, before calculating the number of pounds of terra alba lost through its solubility. In regard to the amount of suspended mineral in the back-water, it is not intended in the question that this should be taken into consideration at all. The question is supposed to contain all the necessary data, but the fact of Mr. Gray putting it in adds to the value of the answer and shows his ability to conduct an original investigation. It is quite true that the figure given for the amount of ash on igniting terra alba collected at the sand tables is lower than that of the original; but it is, in practice, the case, on account of the greater amount of water that the former would contain. It would be in a sloppy condition instead of a semi-dried powder. Mr. Gray is quite correct in the way in which he arrives at the equivalent of the original terra alba lost, and that found on the sand tables, etc. Mr. Gray's only real error, of any moment, is his omission to take into consideration that the terra alba as it exists in the paper is $CaSO_4 + 2H_2O$, whereas as burnt ash it is merely $CaSO_4$. When he puts down terra alba as paper 15·2 per cent. he is wrong, from the fact that he is including the moisture of the terra alba as contained in the original as forming a part of, and giving weight to, the paper. Setting aside the slight error in the calculation referred to in the early part of the answer and taking Mr. Gray's figure for weight of terra alba as 2386·56, we must calculate this into dry crystallized terra alba before we can deduct

the weight of that which is lost, as the weight of the latter is based on the assumption that 0·022 lbs. of crystalline terra alba is dissolved by every gallon of water.

$$CaSO_4 : CaSO_4 + 2H_2O :: 136 : 172.$$

$2386{\cdot}56 \times \frac{55}{100} = 1312{\cdot}6$ lbs. of $CaSO_4$ or anhydrous terra alba

$$= 1312{\cdot}6 \times \frac{172}{136}$$

$= 1660{\cdot}0$ lbs. $CaSO + 2H_2O$, or dry crystalline terra alba.

On deducting the amount of terra alba lost (*i.e.* 676 lbs.), we have 984 lbs. crystalline dry terra alba in 5 tons of finished paper. The percentage of dry crystalline terra alba in paper is calculated as follows :—

$$\frac{984 \times 100}{5 \times 2240} = 8{\cdot}79 \text{ per cent.}$$

The ash is got by converting the crystalline back to the anhydrous terra alba, thus—

$$8{\cdot}79 \times \frac{136}{172} = 6{\cdot}95.$$

O sent a type-written answer, but no name. **O** will see from the above calculations where he has failed in his answer. He has not followed the calculations through, but has merely given an expression of opinion as to how much should be retained under the circumstances. He has, however, taken note of the water of crystallization driven off by heating. " But the terra alba as put into the engine contains only 55 per cent. ash, in allowing for water of crystallization driven off, 70 per cent. ash in the normal state. We must, therefore, deduct 30 per cent. from the terra alba as it goes on to the cylinder." **O** succeeds where Mr. Gray has shown weakness. $55 \times \frac{172}{136} = 69{\cdot}69$, which **O** calls 70 per cent., which is quite near enough.

CHAPTER VII.

THE USE OF ALUM IN TUB SIZING.

Penetration of waterleaf—Temperature—Strength—Influence of alum—Addition of soap—Means of control—Methods of sizing—Viscosity of size—Methods of drying—Influence of paper and beating.

QUESTION 7.—*What is the exact influence of alum upon gelatine, both before and after its application to paper? How does the use of alum enable us to regulate the amount of gelatine absorbed by the paper?*

B points out that alum preserves gelatine from putrefaction, and therefore when applied to paper renders it still more resistant to the action of damp air, etc.

Most of the students mention that alum preserves the gelatine, but **B** is the only one who notes that it is particularly valuable in damp air. In dry air at certain temperatures, dry gelatine such as finished paper would contain would not be liable to putrefaction; it is in moist, warm air that gelatine putrefies so readily, and alum tends to prevent this.

He mentions the use of "formalin" and has got good results with small quantities. In reference to the cause of "shangles," he says: "I used to have an idea that 'shangles,' as they are called by the sizemen (the glittering spots which show up on the surface of some tub-sized papers), were due to alum deposits, but they are only seen in paper which has been reeled straight off and where the size has not had time to thoroughly soak into the paper, consequently it gets a large proportion of surface sizing, and if the drying has been 'hard' the gelatine cracks and 'shangles' are produced." His conclusions require further verification.

C states that alum decomposes the soap put into the size.

This is one of the important functions of alum. He also says it enables the paper to take on a better finish: using less alum more gelatine will be absorbed. This is true providing the amount of alum is small. If a lot of alum is used, the size solution becomes thin again and a larger amount of size would be absorbed, as is explained later.

D explains this point correctly; he gives the amount of alum for a given weight of hides. He says that it gives the paper a harder rattle, and alum should not contain any free acid, as it affects the rags and makes the colours fade. It is far more important that the alum used in the size trough should contain no free acid; this is not so important as for the alum in the chest. "Free stuff absorbs more size than wet stuff, and the sized reels should be allowed to stand a few hours before passing over the driers," are good remarks.

E.—It is wrong to regard alum as a fixing agent for gelatine, nor does alum "curdle" gelatine, but it has the effect of forming a flocculent precipitate with the soap added to the gelatine, and provided the soap is of the proper chemical nature this precipitate does not form a curd, but remains suspended as fine particles as an emulsion.

F says, "If you put a little alum to the gelatine it will thicken it very much, so that you can take it out of the hand-bowl in the form of a stiff mass; by adding more alum you again make it quite thin. I don't like using more alum than I can help, but some must be used to preserve the gelatine."

He also explains how the amount of gelatine taken up by the web can be determined, by noting the difference in the weight before and after. The addition of alum affects the "feel" of the paper.

H says that size would go bad in 30 hours after soap was put in if alum was not added. This would depend largely upon the temperature and dampness of the air. Alum would tend to precipitate any impurities contained in the gelatine prepared from hide pieces. Alum tends to make the paper hard and brittle, and also to make "sparkles" on the surface.

I shows the influence of alum already existing in the paper upon the absorption of gelatine. The greater the amount of alum in the chest, the less the absorption of gelatine in the trough.

J states that soap should be added first, or the size will curdle. This is important to note; also that the soap prevents the "sparkling." He explains that this is seen when running

the paper straight from the "sizer" on to the "dryer," and is most noticeable on the under side. He also realizes the fact that the alum decomposes the soap, liberating the fatty acids which enables the paper to take on a better finish. Alum added to size as above does not for the most part exist in the finished paper as such, at least when soap is also added.

K describes pretty fully the change that gelatine solution undergoes on the addition of alum, and how alum acts as an antiseptic. He says that the alum serves to brace up the gelatine. This is a good expression. Alum may also be said to "brace up" the fibres of a paper.

N.—"More alum should be added in warm weather than in cold." This remark should be noted by others.

U.—The use of alum also hardens the paper, partly no doubt on account of the action of the alum on the cellulose itself. Alum affects the paper, and in doing so it affects also its sizing qualities, apart from any action the alum may have upon the gelatine.

V gives the amount of alum as about 20 to 25 per cent. on the raw material. Of course the temperature of the size is also an important factor. It is advisable sometimes to have it fairly hot and at other times to have it cooler, according to circumstances.

This question is one of considerable technical importance to makers of high-class papers, and it has already been discussed by the writer at some length in Chapters on Paper-Making, Vol. II., and also on the Fibrous Constituents of Paper.

As a high-class paper is only half made by the time it has passed over the drying cylinders, *i.e.* at the stage of the water-leaf, its physical qualities due to the various fibrous constituents are in a semi-latent state and only half developed. It will therefore be necessary for us to consider carefully the next stage of treatment, viz., the tub-sizing process, more particularly in regard to the details which are likely to affect those physical qualities of the papers we have had under consideration. Ordinary water-leaf, providing that it contains no "rosin-size," is more or less of the nature of blotting-paper. If a drop of ink is allowed to fall on its surface it immediately soaks into the body of the paper and makes its appearance on the other side. If wetted by pressing against the tongue, it immediately shows the mark right through; where wetted it is rendered weak, so that the finger is easily poked through the wet mark. Such paper, for all ordinary purposes, requires to be sized, so that it will bear

ink on its surface without allowing it to penetrate. Furthermore, water-leaf has a soft, raggy "feel," and is too weak when the least bit damp. It requires for many purposes to be hard and rigid, and to have a "rattle," and to possess what is vulgarly known in the trade as "guts." These qualities are given to the paper either by rosin-sizing or by impregnation with gelatine. The manner and the extent to which the gelatine affects the paper is dependent on several factors which we shall now briefly enumerate.

In the crudest method of sizing hand-made paper, a bunch of dry water-leaf sheets are held, five to eight in number, between the finger and thumb by one corner, and dipped vertically into a gelatine solution (which should be kept at a constant temperature) as in *A*, Fig. 1, page 38. The sheets, after reversing to allow the top corner to be immersed, are hung over lines in a loft to air-dry. This process of sizing is commonly known as tub-sizing, and the process of drying is commonly known as loft-drying. The same process can be performed in the web as in *B*, Fig. 1. The paper is passed in a continuous web over a roller into a solution of gelatine contained in a vat, which should be steam jacketed to maintain a constant temperature. On emerging from the vat the treated paper is squeezed between brass squeezing rolls, to remove any excess, which falls back into the vat. We shall speak of this method as surface-sizeing (Fig. 1, *A* and *B*), because by passing the web vertically downwards and quickly through the solution, or by dipping hand sheets in a similar position, the air in the interstices of the paper has little chance to escape and so permit the gelatine to enter the pores. The paper is therefore coated only, instead of being permeated, the gelatine residing on the surface.

The reason that tub-sized paper frequently contains the greater portion of the size at or near the surface only is not necessarily due to the size not having penetrated in the first instance. It is not infrequently due to the fact that, in the course of drying the tub-sized sheet is exposed to too high a temperature, the gelatine rises through the body of the paper to the surface, and forms a film. During such drying the gelatine is abstracted from the body of the paper and comes to both surfaces.

In order to allow the gelatine to enter into the body of the paper, it is best to cause it to float on the surface for a short way before immersing it, until the top surface shows that the gelatine has permeated. This can be accomplished by hand, as in *A*, Fig. 2, page 42, and by machine in the continuous web, *B*. In the latter

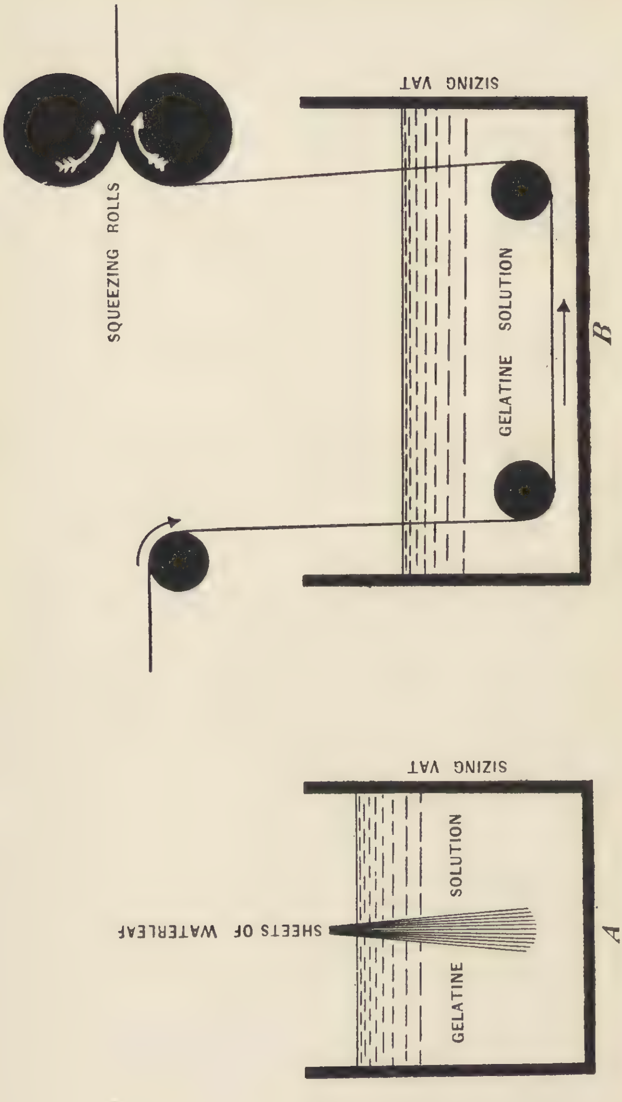
SQUEEZING ROLLS
SIZING VAT
GELATINE SOLUTION
B
SIZING VAT
SHEETS OF WATERLEAF
GELATINE SOLUTION
A

FIG. 1.

case a steam-jacketed vat is provided with sloping sides lined with copper or lead, to protect the sides from the corrosive action of the alum. The "water-leaf" meets the surface of the gelatine at an angle, and is made to travel in contact with the liquid without wetting the upper surface, and for such a distance as to enable the size to pass through the body of the paper to the upper surface. The paper is then made to dip under the gelatine solution, and then passed through the squeezing rolls. It might appear difficult to wet the under surface without allowing the liquid to flow over the top surface, but in practice this is not a difficult matter, as the under surface becomes wet, expands, and causes the edges of the paper to curl up, thus presenting a barrier to the flow of the solution over the top surface.

There are, however, important modifications of the above-mentioned methods. It is no longer the custom, in the best mills, to dip the sheets in bunches in the vat. The same process is imitated by clamping a large number of sheets together, and suspending them in clusters in a vat, which is filled with hot solution of gelatine. The sheets are allowed to remain in the vats a sufficient length of time to allow the air to escape and the size to take its place in the pores of the paper. The sheets are then removed and passed through a pair of squeezing rolls, or stacked and pressed, then separated and hung up to loft-dry.

In another process the sheets are taken a few at a time, and passed through a solution of gelatine contained in a large shallow vat. The sheets are drawn along between an upper and a lower felt; the upper felt is perforated in order to allow the air to escape more readily. The machine is either actuated by a hand-rack motion, by which the workman brings forward a batch at a time; or the felts are made to travel slowly and at a uniform speed through the solution. The vat must be long enough (say 30 or 40 feet) to admit of a fair output of sized sheets to remain immersed in the size solution sufficiently long for a proper penetration. There should be no air bubbles rising through the liquid close to where the sized sheets emerge and are discharged. The bunches of sheets are fed on to the felts, say eight in each batch, and from one to three abreast, according to the size of the sheets and width of vat.

The felt carrying the water-leaf travels at a very slight incline, so as to allow the air to escape more easily. The solution is only just deep enough to ensure immersion as the sheets travel horizontally the whole length of the vat. The temperature of the

solution is maintained either by steam-jacketing the bottom, or fitting it with a steam coil. The latter, although perhaps cheaper, is much more difficult to cleanse. Various modifications of this plant are in use.

Beyond the mode of treating the size, there are other and no less important factors which influence the quantity of size absorbed by the water-leaf. The rate at which the web of paper passes through the vat is, of course, a determining factor. If a higher speed is required, a longer vat must be used to give sufficient time for the immersion. As the rate of impregnation is dependent upon the viscosity of the solution, and this again dependent upon the temperature, the latter must be carefully controlled. The higher the temperature the lower the viscosity, and as a consequence the more rapid the rate of penetration. Then, again, the percentage strength of the gelatine solution affects the viscosity; the greater the percentage strength the greater the viscosity. A size of high strength, therefore, permeates more slowly than one of low strength. The amount of moisture contained in the water-leaf before it passes into the size solution will affect the rate of impregnation; within limits, the moister the water-leaf the quicker the impregnation; thus a bone-dry water-leaf takes up the size solution less rapidly than one containing an appreciable amount of water. In order to ensure regularity in drying the water-leaf, it is generally advisable to bone-dry it, *i.e.* to deprive it even of its natural moisture. If the moisture in the water-leaf were brought down, say, to 7 per cent., there is a danger of the paper being moist in patches. The result would be to cause irregular soaking up of the gelatine, so that the paper would vary locally in the amount of gelatine it contained. This is liable to cause a blotchy appearance in the paper, both when looked *at* and when looked *through*. Moreover, when the water-leaf is damp, the web, which is extremely tender as it passes through the sizing trough, is liable to break and cause a lot of trouble, expense, and inconvenience. I have known the web broken in the trough by a rat plunging into the hot size and swimming from one side of the vat to the other. The least touch will cause a break.

In spite of the comparative slowness of absorption of the bone-dry water-leaf, it is considered advisable to bone-dry it before allowing it to pass through the sizing trough, for the reason above mentioned. The presence or absence of soap and the proportion of soap used are determining factors. Soap is dissolved to a clear solution in hot water, and added to the hot

size solution before or after the alum. The soap must be of such a nature that when mixed with the gelatine, and subsequently with alum, no curdling by separation of fatty acids, or compounds of the fatty acids and alumina, occurs. This can only be ensured by using soap of a peculiar character, which forms a fine emulsion evenly distributed throughout the mass. Soap tends to give a certain amount of opacity to the paper, but the extent of its effect in this direction is doubtful. It, however, gives desirable qualities to the finished paper ; among them may be mentioned the lubrication of the fibres. Some papers have a disposition, when cut with the guillotine, to cause the knife to go through with a bang. Paper containing soap, preferably added in the chest, permits the knife to glide evenly through the stack of paper. It is also possible that a lower grade of gelatine can be used without prejudice to the colour of the paper ; the soap being held in fine white emulsion disguises the colour of the gelatine.

We have so far considered only water-leaf which has not previously been sized with rosin. In consequence of the great expense of tub-sizing with gelatine, paper-makers use, as far as possible, the cheaper grades. This is very doubtful economy. I am strongly of opinion that a deal more good might be done by the use of a high-class gelatine in small percentages, but imparted to the paper and dried in such a way as to produce its maximum effect. So far this subject has received little attention at the hands of paper-makers, who prefer to reduce their cost of production by using a low grade gelatine or glue, or by the addition of rosin size in the chest, which renders the paper more or less ink proof, and prevents it taking up so much gelatine solution when passing through the vat. Twenty years ago tub-sized papers contained no rosin size ; now, so far as my knowledge goes, the greater bulk of them do, although the best of them still do not.

A web of water-leaf surface-sized would take up, perhaps, 30 per cent. less weight of solution than if body sized by the method shown in Fig. 2. The percentage of size taken up by the paper is also controlled by varying the percentage strength of the size solution—the most obvious way of controlling it ; but as the amount of moisture taken up by the paper has to be dried out of it again, and as the cost of this operation is considerable, as the drying must be effected at a low temperature to preserve the sizing qualities of the gelatine, manufacturers generally prefer to control the percentage by varying the impregnation of the paper ; and this is frequently done by adopting one or

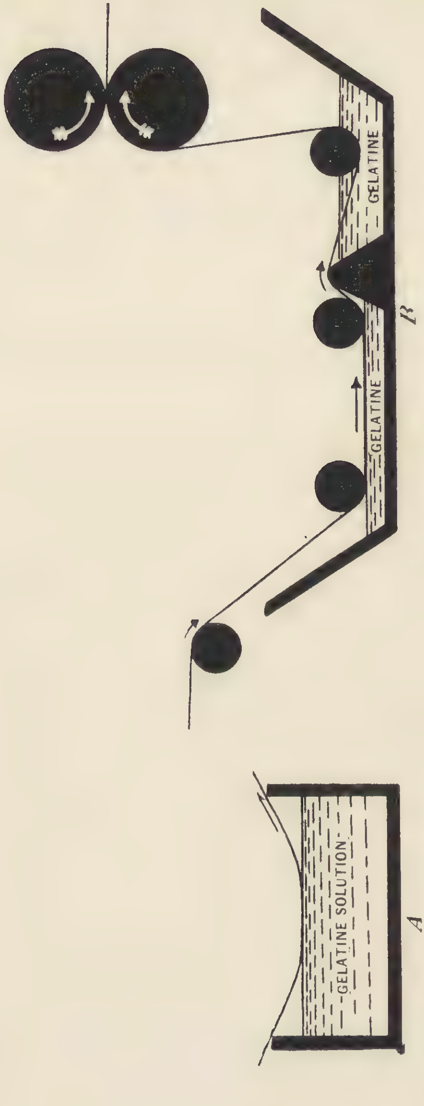

FIG. 2.

other of the methods illustrated in Figs. 1 and 2, and by varying the strength of the gelatine solution between 4 per cent. and 7 per cent.

The amount of solution retained by the treated paper is dependent, of course, upon the amount of pressure on the squeezing rolls. To allow of the paper being properly handled afterwards, the pressure on the rolls must be sufficient to prevent the surface of the moistened paper being sticky, otherwise there is likely to be trouble in the subsequent drying operations. On the other hand, if too great a pressure is applied, especially with papers of a spongy nature, there is a liability of breaking up the microscopic films of gelatine, which fill the interstices between the fibres. When these disappear the paper is no longer ink-proof. The pressure on the rolls can therefore only be varied within certain limits. The temperature must not be raised to a point likely to injure the gelatine solution, but it may with safety be varied between 85° and 120° Fahr.

One of the most important means of control is the addition of alum. Alum affects the viscosity of gelatine solutions in a very curious manner. If a hand-bowl containing a good class gelatine solution, say 5 per cent., at a temperature of 95° Fahr., is stirred by the hand whilst a few drops of alum solution are added, a thickening effect will be noticed. On further addition of alum this will reach a maximum—the solution may become almost a jelly ; on further addition of alum it becomes liquid again, until it becomes even less viscous than the original solution containing no alum. The size-man controls the penetration of the size by the addition of alum. If he finds that he has overshot the mark with alum, he adds more size containing no alum, and thoroughly mixes the ingredients. If he wishes to increase the viscosity or "thickness" of the size in the trough, he adds more alum and thoroughly mixes, but he should never use so much alum as to anywhere nearly reach the maximum viscosity as indicated in Fig. 3. If he has overshot the maximum and got a thin size by the addition of too much alum, the size is said to be "killed," as it is nothing like so effective as a size of the same strength with the proper amount of alum added to it ; besides which, the addition of too much alum is extremely wasteful, and the excess of alum gives to the paper an acid reaction, which is considered undesirable for many purposes. As the rate of penetration of size into paper is *cæteris paribus* inversely proportional to the thickness (*i.e.* viscosity) of the size solution, the dotted curve, Fig. 3, which is merely an inversion of plain line curve, is made

to represent the change of power in permeating water-leaf on addition of alum.

The somewhat strange behaviour of size when mixed with alum, as exemplified by the above diagram, is capable of scientific explanation. Size and glue consist of two distinct yet similar compounds, known respectively as gelatine and chondrin. Chondrin is thrown out of solution by alum and several other compounds which do not precipitate gelatine. Size, glue, and commercial gelatine consist of mixtures of gelatine, chondrin,

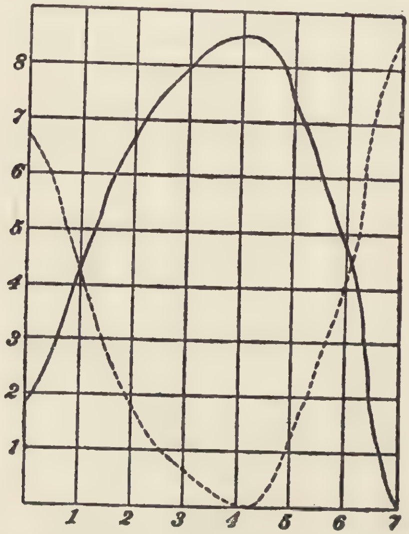

FIG. 3.—CURVES SHOWING THE VISCOSITY OF GELATINE SOLUTIONS, FOR VARIOUS PERCENTAGES OF ALUM ADDED.

The curve drawn thus ——— gives the viscosity, and that drawn thus - - - - the permeating capacity of the solution.

and the non-gelatinising substances produced by the long boiling and oftentimes over-heating of their solutions.

If it is considered desirable to prevent the paper becoming body-sized, we have yet another means of doing this, and that is by adding alum to the chest in sufficient quantity to give excess of alum to the dry water-leaf. This, when it comes in contact with the size solution, coagulates the gelatine in the surface, and the coagulated gelatine has no power of penetration. This can be controlled, of course, by the amount of alum added to the

chest. This result can hardly be achieved without wasting a considerable amount of alum, unless the "backwater" of the machine is saved and used over again to the best advantage.

Some of the mills in this country have for fifty or sixty years, or perhaps from the advent of the Fourdrinier machine up to a few years ago, combined the manufacture of paper with tub-sizing, and drying as a continuous process. There are obvious disadvantages in this. The rate of travel through the sizing-troughs has to be the same as that of the "wet-end" of the paper machine. This may or may not suit the sizing. The paper comes away from the drying cylinders bone-dry and hot, and plunges at once into the size solution. Some advantage might be gained by reeling the paper after it is dry and allowing it to settle itself down and cool in the water-leaf, so as to allow it to get to its normal condition before the tub-sizing process; but perhaps the greater disadvantage is found in the drying. The wet-sized paper contains about 50 per cent. of gelatine solution, and 50 per cent. of air-dry paper if body-sized; if surface-sized, from 30 to 40 per cent. of gelatine solution, and 60 to 70 per cent. of air-dry paper. As the gelatine solution contains about 5 per cent. of air-dry gelatine, 95 per cent. of the solution is water which has to be removed by the drying process. Roughly speaking, as a maximum with body-sizing, for every ton of paper produced at the cutter, one ton of moisture has to be evaporated. As this evaporation has to be conducted at a low temperature by means of dry air, the process is of necessity a slow one; in order to keep pace with the output of the paper machine, provision has to be made to dry a length of from a half to three-quarters of a mile in continuous web. If the paper is reeled, either before or after sizing, or both, the speed of sizing is independent of that of the paper machine; and if the machine is at times only producing soft size papers, *i.e.* paper sized only with rosin, the sizing plant can work off any accumulated stock of unsized water-leaf. It is generally admitted that reeling, after sizing and before drying (*i.e.* immediately after passing the squeezing rolls), and allowing to remain in a damp condition, so as to permit the size solution to more thoroughly permeate the paper, gives a better result than if the sized paper is immediately dried after immersion. The best plan, therefore, is to reel the water-leaf, and to allow the reels to stand some hours or days; then to unreel and pass through the sizing vat and to re-reel; and when the reels of damp-sized paper have been standing a sufficient time, to unreel and pass over the drying plant.

The skeleton drums previously referred to are provided, in their

interior, with rapid rotating fans, which are speeded up in sections. These fans drive the air against the surface of the paper, and so increase the rate of drying. The impinging of the air on the surface of the paper would tend to keep the temperature of the paper below that of the surrounding air by reason of the rapid evaporation. This is a most desirable thing, as will be hereafter explained. But the paper is kept under a certain amount of tension by this treatment, and in a state of quiver by the rapidly rotating fans. This, I am disposed to think, is undesirable, and likely to break up the microscopic films of gelatine in the interstices of the paper. It is possible to produce a hard-sized paper with a small percentage of gelatine, by dipping the water-leaf and allowing it to dry slowly in a loft, when the same amount of gelatine produces an inferior result if the paper is dried over skeleton drums. This fact would lead us to suspect that the fans have a bad influence. It is most desirable that the drying should be done naturally and slowly, without agitation, and above all things, at a low temperature. This is now, in a large measure, accomplished by a machine which takes the wet paper along in festoons by a slow gliding motion through a drying chamber, at such a speed that when it emerges at the other end it is air-dry. This process admits of a natural shrinkage during the drying, and the paper remains quiescent, but the method is far short of perfection.

The drying of tub-sized papers is, perhaps, one of the most difficult problems presented to the paper-maker. Gelatine has little or no sizing effect if dried over a steam cylinder. The heat liquefies the gelatine, and it dries merely as a coating to the fibres, the spaces between them being left vacant. The gelatine is not destroyed, but is without any effect ; it merely coats the individual fibres, and is quite discontinuous. Although this is a well-known fact to all papermakers, many of them think there is no harm in using a certain amount of artificial heat in the air used for drying. If we lived in a very dry climate, the air might have enough drying power at about 50° Fahr. to dry the moisture out of the sized paper ; but unfortunately, if one takes the records of the Meteorological Office, the average percentage saturation, in many of our manufacturing districts, is found to reach 80 per cent., and frequently borders on 100 per cent. It is impossible, therefore, to obtain drying power out of the air at ordinary temperatures, unless we give to it a certain amount of artificial heat, and this is generally what is done. The golden rule should be : Dry the sized web at a temperature below the setting point of the

jelly. The wet size in the paper should get to a jelly before the drying operation, so that instead of drying water out of a gelatine solution, we are really drying water out of a solidified jelly contained in the interstices of the paper. So long as the temperature of the air is above that of freezing point, and there is sufficient drying power in the air, drying can be conducted properly; but when once the warmth of the air liquefies the jelly, the sizing becomes defective.

If a good class of gelatine is used, a lower percentage solution will remain as a jelly at any given temperature up to 60° Fahr. than with a low-class gelatine, and the sizing effect with the more expensive gelatine far outweighs the additional cost. In other words, we can obtain a firm jelly at a cheaper rate by the use of a more expensive gelatine. It follows, therefore, that at the temperature at which tub-sized papers are now dried, a greater amount of gelatine is used than would be necessary if a lower temperature were maintained. A cheap process for drying paper at a low temperature is much to be desired. Great strides have been made in the desiccation of air by refrigeration for use in blast furnaces; possibly the same might be applied to the drying of paper.

Tub-sized paper is often improved by sprinkling it with water after drying, stacking it, and again drying it; but care must be taken to prevent the development of liquefying bacteria and moulds, which destroy the sizing quantities of the gelatine. Such a process can only be of advantage where the drying has been badly done in the first instance.

Cotton, linen, hemp, jute, wood, all behave differently with size solutions, and require different quantities of gelatine. The manner in which these fibres are beaten and felted together also has a material effect upon the sizing qualities. This is a subject outside the question which we are now discussing, and one on which much has been written.

Finally, calendering, plate-glazing, rolling, etc., affect the sizing qualities. A paper which has been highly glazed under pressure between copper or zinc plates is often reduced in its ink-bearing qualities. It is easier, therefore, to produce a hard-sized paper with a rough surface than one which has been highly glazed. Elsewhere I have mentioned that tension on the paper in course of drying tends to destroy the ink-bearing qualities by breaking up the films of gelatine; pressure has the same effect. As bearing on this question, it should be noted that when tub-sized paper is tested for breaking strain whereby it is permanently

elongated by the pull of the machine, it loses almost entirely its ink-bearing qualities.

When single sheets are loft dried they are more or less rough, and show a mark which is removed by subsequent pressing ; but the system of drying over skeleton drums, whatever else its defects may be, produces a paper perfectly smooth and free from cockles, without any pressing or glazing.

CHAPTER VIII.

THE INFLUENCE OF TEMPERATURE ON BLEACHING.

Rapidity of action—Critical temperature—Influence on cellulose—Overheating—Saving of time.

QUESTION 8.—*Give your reasons for and against raising the temperature of the bleach in the poacher. What precautions would you consider necessary?*

B makes an inquiry as to the increase of temperature occasioned by the bleaching action in a given mass of pulp. This raises a very important point, on which I must confess that I have no knowledge, and I do not think any determinations have ever been made. It would be possible to make a calculation (which, however, might or might not be borne out in practice), the necessary data for which would be as follows: The weight of pulp, water, and of metal forming the bleaching receptacle must be ascertained, and the rapidity of action measured by the absorption of chlorine over a given length of time must be determined by titration. From the last mentioned must be calculated the amount of oxygen consumed per hour. The heat liberated could be calculated from the ascertained calorific value of cellulose when burnt in oxygen. We should then be in a position to calculate the rise of temperature on this basis due to the bleaching action alone. It could not be argued with any degree of certainty that this basis would be a correct one in practice, but the probability is that the amount of heat arrived at by this calculation would not be exceeded in practice. It must not be forgotten that agitation will modify the result by increasing the loss of heat by increased evaporation from the surface. On the other hand, the temperature would be raised by mechanical agitation, the energy of the latter being converted

into so much heat; this latter would have to be ascertained by a blank experiment, and deducted from the former.

"By raising the temperature the energy of bleaching is accelerated." It would be better in place of "energy" to say "rapidity," because the efficiency—*i.e.* the chlorine consumed per unit of bleaching effect—is diminished with the increased temperature. He speaks of the chlorination of lignified fibres, and refers to the fact that heat is liable to give a bleaching effect that goes back in colour. "If I had occasion to use steam I should take the precaution of warming the disintegrated pulp before adding the bleaching liquor." He recommends for straw and esparto a maximum of 100° Fahr., and for wood 90° Fahr.

C, in common with several others, remarks that the temperature of bleach in the poacher is raised when the material is dirty, and to save time.

D remarks that "bleaching in the cold would require a much longer time and more bleach." It is possible that he might be misunderstood here. The fact is, that to do the bleaching in a very limited time in the cold, a larger amount of bleach would have to be present than if the stuff were warmed, on account of the comparative slowness of cold bleaching. Supposing, for the sake of argument, we required 20 lbs. of bleach to do a given amount of bleaching in two hours in the cold, and 15 lbs. to do the same amount at 90° Fahr. At the end of the time we might find that the cold liquor contained the equivalent of 10 lbs. unconsumed, and the hot liquor 3 lbs. Although we should have been compelled to add more liquor for the cold bleach, yet the amount actually consumed would be larger in the case of the hot bleach. If, however, in the one case we bleached in the hot with such quantity that the whole is consumed at the end of the bleaching, and in the other case used a cold solution which just exhausted itself, we should find that the hot bleach would consume from 20 to 50 per cent. more bleaching powder than the cold solution. The additional consumption would depend upon the extent to which the temperature was raised, and also upon the material operated upon. **D** remarks that "the effect of overheating is more noticeable in high-coloured rags. They take on a brown colour, and the rag becomes very fine and seems to go into solution." This is very expressive. The rag does go into solution on account of the formation of oxycellulose, which in presence of alkalis turns brown, and partially enters into solution. **D** remarks in common with others that "they should be immediately washed off, or the colour will go back." The temperature must be

lowered immediately. The bleaching is completed by a rapid wash in cold water.

E remarks, "if the temperature exceeds 100° Fahr., the chlorine, instead of merely bleaching the non-cellulose matter, attacks the cellulose itself, and forms chlorides which are impossible to remove by washing." It is only lignified fibres which combine with chlorine, and the cellulose itself is not attacked, but the non-cellulose or lignine forms a bright yellow compound, soluble in alkaline liquors. When the cellulose itself is attacked it is a question of oxidation, not of combination with chlorine.

F goes into the subject of the cost of raising the temperature as a reason against so doing. This, of course, is an important factor in the question. A full answer might well have given the cost of raising the temperature to 90° or 100° Fahr. from the temperature of spring water, of a temperature say of from 40° to 45° Fahr. Any observer could easily work this out from data given in BEVERIDGE'S BOOK.* The cost of coals, and the additional cost for consumption of bleach, is a set-off against the saving in time. Other factors are the liability of injury to the fibre in strength and in colour. Many of the students draw the line at 90° Fahr.; others draw the line at 100° Fahr. The class of material under treatment and the general conditions of working would affect this question, which I hope we shall be able to discuss on some future occasion.

G has expressed himself so well and to the point, I will quote his answer in full. "When the temperature of bleach is raised in the poacher, chlorine is liberated more quickly, and more rapid oxidation takes place, and so results in a considerable saving of time. Against this we have the fact that about 20 per cent. more bleach will be required to get the same result. Also, if the temperature should rise above 100° Fahr. the cellulose will be attacked, the fibre will not be so strong, and the stuff will have a yellowish shade. The only advantage of raising the temperature is the saving of time."

H remarks, "When using steam it is better to allow the bleach to become thoroughly mixed before heating it; great care must be taken to see that the steam-cock will close tight or the stuff will be overheated." This is very important.

I remarks, "If the stuff in the poachers is allowed to bleach in the cold it will require a long time, also a large amount of power for circulation." I would point out that if there were

* PAPERMAKERS' POCKET BOOK, Beveridge.

much bleaching to be done it would be hardly practicable to keep the stuff in the poacher all the time. It would be advisable to empty into a steeping tank after thoroughly mixing, but, of course, he is right in leading us to believe that additional time in poacher means additional cost for power, etc. "Heat drives off some of the bleach in the form of vapour." This is more noticeable when an engine is overheated. I do not think there is much in this, at any rate from the point of economy, although it may occasion inconvenience to the workers. The actual loss when the temperature is kept within bounds is too small to affect the question from an economical point of view, and if it should get out of bounds and "cause sneezing," etc., it is an indication to the man in charge that he is not doing his work properly, and is a little wasteful. "Steam when entering has a tendency to lift the emptying valves," etc. I think the vibration might be diminished by introducing the steam jet in a proper way, and so obviating this vibration. Any difficulties arising from this cause are the fault rather of the general management than the result of resorting to hot bleaching, and therefore can hardly be considered in connection with the question. The eating away of the metal, due to the more corrosive action of the warm bleach, is certainly a point in favour of bleaching in the cold. "**I**" points out that should the stuff have to stand for a day or so it should not be heated. This applies to newly furnished engines on the Saturday night.

J considers that hot bleaching in the poacher should only be resorted to when the material is very dirty or highly coloured. As we have already seen, there are many instances where such bleaching can be used to advantage. It might be fairly stated, however, that in mills where rags only are treated and the bleaching is generally done in the cold, it is found advantageous to use the hot bleach for accelerating the bleaching action with dirty and high-coloured rags.

K remarks that heat enables us to bleach a large amount of pulp with a comparatively small plant. His remark that as "warm water is more readily decomposed than cold water the bleaching process is hastened" is somewhat to the point, but it would be better to put it in a more general way by saying that bleaching by means of bleaching powder belongs to that class of chemical reactions which is accelerated by heat.

L considers that "raising the temperature of the contents of a poacher will assist in the work of bleaching by softening the dirty or undesirable matter still adhering to the fibres." This is

a practical remark. Some papermakers object, and with reason, to bleaching dirt contained in rags which they consider would come away in the breaker. But there is much dirt that is not only bleached, but is also rendered less adhesive, and consequently more easily removed in the breaker wash after bleaching.

M goes into the theory of the chemical action, pointing out that the bleaching is due to the chlorine combining with the hydrogen of the water and liberating oxygen in the nascent condition, which oxidizes and destroys the colouring matter. He makes one practical remark which probably accounts for the general practice of heating esparto stuff to about 100° Fahr., and so accelerating the chemical action as far as possible. If esparto stuff were thus treated (in the cold) in the ordinary poacher it would be all run into knots before it reached a good white colour.

Q.—I do not know how far **Q**'s remarks are true, namely, that "heating tends to liberate such dirt and the fibres can then come in contact with the bleach." I do not think that the heat assists much in the mechanical removal of the dirt. This is a question rather of agitation than of heating.

R justly considers that the best and most lasting colour is got when no heat is used. "This is borne out very well when, say on Saturday, no steam is added and the stuff is allowed to stand over Sunday. The carbonic acid in the air helps, I believe, to bring up the colour." This remark would apply to bleaching where agitation is going on, but the carbonic acid has very little effect when the mass is at rest, except in those portions immediately in contact with the surface. **R** recommends the following precautions: "To see that the stuff is well washed before adding the liquor, and regulate the heat by periodical testing with the thermometer." The use of a thermometer is absolutely necessary; it is no use trusting to the hand. A liquor that would feel warm on a cold morning would feel comparatively cold on a warm morning. The thermometer is the only real guide. The best mode, however, is to heat the stuff up to the requisite temperature before adding the bleach, as the danger of overheating is thereby absolutely avoided.

U speaks about the necessity for good circulation, and "if a portion of the pulp should be opposite the steam pipe for some time it gets overheated, injuring the pulp and causing uneven colour." This is another reason for heating the pulp before the addition of the bleach liquor.

V points out that overheating results in a brittleness in the paper, due to the formation of oxycellulose. The going back of the colour he attributes to the formation of organic chlorides. This is not often the case. The loss of material by overheating is very considerable. From experiments it has been found that as much as 25 per cent. has been wasted.

I do not think he can mean that 25 per cent. has been lost over and above what would have been lost by cold bleaching, because this would be enormous, and could hardly be possible, unless nearly the whole of the cellulose had been attacked and converted into oxycellulose. It is quite possible that by overheating we should get a total loss of 25 per cent., when we should get a loss of 18 per cent. by bleaching in the cold, giving a difference of 7 per cent. due to the cellulose being attacked at the higher temperature. He advocates heating the pulp before bleaching, and keeping the temperature at about 90° Fahr., and not heating during the bleaching.

The various answers make no mention of one drawback possessed by hot bleaching, especially in the case of rag treatment, of which I will give a description. Boiled rags were formerly bleached in the old-fashioned tumblers, but for many years now some mills have bleached the rags by piling them up in chambers and promoting the circulation of warm bleach through the mass, much on the same principle as that of a vomiting boiler, but taking care that the temperature does not rise above 95° Fahr. The rags are not disturbed during the treatment, but the liquor is in constant circulation through the mass, and the action is very rapid, and produces a very good colour. The liquor is immediately drained off. If the rags are at once transferred to the beaters after douching them with cold water there is no fear of injury, but if left piled up in a warm condition the centre of the mass undergoes a most curious change. On turning the mass over for its removal to the breakers after, say, a fortnight, or even after a few days, we notice a sweet beeswax-like smell. Whilst the rags are being broken in, if one looks along the surface of the water after it leaves the back-fall, a thin film is often noticeable. If much of this class of rags are used in the breaker the surface of the latter is soon coated with a thin wax-like film, which can easily be scraped off. This film has been submitted to careful examination. It may become a source of constant annoyance by breaking off and finding its way into the paper. Under these conditions of hot bleaching, instead of the bleach converting the cellulose into oxycellulose, it undergoes a fatty degeneration by slow conversion

into a waxy substance, which, by treatment with alkali, is easily saponified and converted into a soap. This action occasionally occurs, giving rise to the so-called waxes and resins, and is certainly a drawback to this form of hot bleaching; this action may result also when the stuff is bleached hot in the bleacher and allowed to drain without previous cooling.

CHAPTER IX.

THE USE OF REFINING ENGINES.

Comparison with Hollander—Mode of action—Cases where useful.

QUESTION 9.—*What is the action of a refining engine as compared with that of a Hollander? How far can refiners be made to do the beating with advantage? For what class of stuff would you recommend the use of refiners?*

B.—"A refiner has a much greater cutting surface than a Hollander.

"Its enclosed construction allows of a much greater dilution of stuff, and also admits the whole of the knives to be cutting at the same time.

"The nature of the centrifugal force is different. The shape of the refiner admits of the stuff travelling from a small to a large diameter, whereas in the Hollander the centrifugal force is uniform, and the stuff does not tend to travel *along* the roll. These things help to explain the action of the refiner in producing stuff in a finer state of division in a shorter time than the Hollander.

"In cases where beating means cutting, the refiner can be utilized to save nearly one-fifth of the time required to do the whole of the beating in the ordinary Hollander.

"The following materials may with advantage be passed through a refiner :—(1) Esparto; (2) Straw; (3) Mechanical wood; (4) Broke; (5) Chemical wood and rag, except where the stuff is required long."

The construction of the refiner need not be explained here. All the text books give descriptions. The speed at which the refiner is generally driven is nearly double that of the ordinary Hollander.

Once the stuff has left the refiner, it is never, or hardly ever,

re-circulated. The machine is used in the main, as its name implies, to refine and clear the stuff.

In the Hollander, after the actual beating is performed, the beaterman allows some 20 to 30 minutes to brush out the fibres, to separate them, and to free it from knots; but if he has a refiner there is no need for this, and the time is saved by passing it through the refiner, which accomplishes the object almost instantaneously.

The question of hydration is one of degree only, viz. the length of time the stuff is in the engine when working from the top, and the length of time when using the bottom pipe.

B appreciates the important part played by hydration, which is brought about by an ordinary Hollander, but not in a refining engine, as the time of treatment in the latter is too limited.

C says the "refiner will not injure strength." It will not if it is properly used, but might without proper care. He recommends refiners for fine writings.

D says: "It is used to advantage for strong wet stuff, the knives being blunter than in the ordinary beater, but the stuff must be previously run for some time in Hollander."

E.—"The refiner uniformly reduces to finished pulp all the lumps, lodgments, and knots of stuff which have escaped the Hollander treatment." This is well expressed and to the point. He further states that "they (*i.e.* refiners) are almost unnecessary in a mill where Taylor beaters are used, for the latter do the work of refiners to a great extent, as well as actual beating." One or two of the students realize that refiners can be introduced into a mill for the purpose of saving time in the Hollander, which is generally devoted, with an unnecessary expenditure of time and power, to clearing the stuff. The refiners, in a measure, act as a screen, not by intercepting lodgments, etc., but by reducing them all to beaten stuff.

F.—"The action of a refining engine is entirely a cutting and brushing one. As fast as it can grind its stuff up so fast does it empty itself out. There is no circulation of stuff at all. It is composed of a female conical shell full of knives (bronze knives far preferable), and has one set of knives round the head. Into this female shell goes the male one full of knives. The male is fitted with the shaft, and this being tapered, can be screwed home very tight till the two head brushes rub close together.

"The long stuff is usually emptied into a chest called the 'Marshall' chest, with not much water in it, and when the pulp

is wanted it is passed through the refiner and ground to the fineness required. The less the pulp is diluted in passing through the cone the better it will be.

"An ordinary Hollander has a dished bottom with a large roll full of knives in clumps of three bars, with a bed-plate full of knives at the bottom, and the roll can be lowered or raised as desired, the rags passing between the bed-plate and the roll. The fact that the beater roll has to do the circulation as well as cutting, is the chief distinction between the refiner and the Hollander. The refiner, although taking a great deal of power, is a good machine for its work; you can put any power you like on the Marshall. I have known one indicate on some classes of paper 12 horse-power, and on other classes 80 horse-power. Refiners can be used with advantage on writing paper, banks, and loans. On a writing paper it is possible to get the stuff out of the beater in two hours and empty it all away into one chest, afterwards passing it through the refiner, thus producing a very uniform stuff. The use of a refiner sometimes takes away a lot of responsibility from the beaterman, for he can empty his stuff long, and of even length, after which it can be reduced to the required length by the refiner. The stuff thus refined, although fine, is not soft or wet, and works well on the machine. When marshalling over into the chest where the machine works from, the beatermen empty more water with the stuff. The machine is good for writings, banks, and loans, and is doing good service in our news mills. I should say it is not good for blotting paper."

F, perhaps, does not arrange his answer in a way which would best suit the examiners, but he has evidently a good deal of practical knowledge, and his paper is sufficiently important to warrant publication.

G describes the action of a Hollander as being that of a cutting and bruising nature, and that of a refining engine as that of a brushing nature. He recommends the use of a refiner for all wood and esparto papers, and also for rags.

H gives a very fair description of the construction of a Marshall engine and its mode of action. The following remark deserves notice: "If the stuff is wanted wet or free, according to the requirements of the paper to be made, it must be done in the ordinary beater before passing to the refining engine." He is only expressing in another manner the fact that no hydration can be effected in a refiner, as the process is almost instantaneous, and the hydration takes time. **H**, in common with many other students, says that the thicker the stuff in

passing through the refining engine, the better it accomplishes its work. He ends up by recommending the refiners for all classes of papers except blotting and other absorbent papers.

I's information is mostly contained in other papers, but he puts it in a different manner. He, however, points out the difference in the result obtained in the Hollander and the Marshall as regards finished paper. "The stuff does not go into minute particles when treated in the refiner, as is the case with some of the stuff in a Hollander. This is noticeable in the finished sheet, and is in favour of the former method." There is an advantage in certain instances in having the fibres of different lengths instead of all one length and treatment, but this cannot be discussed here. "The finished sheet from a beater and a refiner is quite different, even if the furnish is the same." He does not consider it at all satisfactory to prepare stuff for a "bank" or a "loan" by means of a refiner, which is only another way of saying that in a "bank" requiring hydrated or wet stuff, which is a matter of time and can only be effected in a Hollander, the use of a refiner is not practicable except for a slight treatment at the finish.

J, in common with many others, describes the action of the knives revolving against stationary discs as though it were an essential part of a refining engine. It must not be forgotten that some refiners do not possess this disc. The students generally appear to be more familiar with the Marshall than with any other refiner. How about the Jordan and the Horne refining engine? The disc cannot be considered as an essential part of a refiner. J considers that refining engines can be used for E.S. printing and almost any sort of paper except blotting and stuff where wetness is very important. It must not be forgotten that the form of the fixed knives influences the cutting power, *i.e.* whether zig-zag or straight, etc.

K gives a very fair answer in a general sense as far as the relative functions of the Hollander and refiner are concerned. He shows that in some mills the Hollander is made to do nearly all the work, whilst in others only about half the work, and the rest is put upon the refiner. In some mills refiners do the whole of the work except pulping.

I should think in the last-mentioned case there is very little beating to be done after the pulping is effected. "Refiners will be of most advantage in working shop-papers, news, low-grade writings, imitation parchment, and grease-proof papers."

L remarks, "When pulp has been treated in the refiner it

makes a harder sheet than pulp straight from the beater. I would prefer them to beaters of the Hollander type where floor-space rather than driving power must be considered."

M is hardly correct when he says the refiner has simply a cutting effect, and his subsequent remarks show that he realizes this. In the following remarks he shows a knowledge of one important function of the Hollander which some do not realize. ". . . whilst the Hollander cuts the fibres, mellows and softens them, and draws them out both by the circulation of the stuff and the weight of the roll."

N remarks that the stuff "can be drawn from the refiners in different grades."

Q presents a different aspect of the question: "Under the action of the refiner the fibres attain a more uniform length, whilst any small knots or pieces of wood receive like treatment. Refiners can be used to advantage in all cases where a mixture of materials are used differing only slightly in strength and texture as in papers largely made from rags, but in papers (browns, I speak of) where a great variety of materials of various strength and texture, such as for making rope browns, refiners have not been worked to advantage, constant jamming causing trouble."

R describes the action of the refiner as a grinding one. Not a bad definition, but I think a "brushing" action is more to the point. "For those (classes of paper) with which I am more familiar the Hollander is preferred for good all-round work." Of course the function of the refiner is a limited one, whereas the Hollander not only does the work of the refiner, but can perform all the necessary functions of beating. He considers the refiner has the merit of mixing the colour better, and enabling the machine man to run steadier weights. **R** realizes that in drawing a comparison between the Hollander and the refiner, it is necessary to take into account the amount of care exercised in the beater. The refiner to a certain extent looks after itself, whereas the beater requires the most careful management.

S shows a practical knowledge: "The action of the refiner is more continous than a Hollander. The stuff in the refiner is under the action of the bars the whole time, but in the Hollander it is only when under the roll that the stuff is affected. Refiners are of no use for beating, as they require too much power. For some classes of stuff, such as wood pulps, a refiner is almost indispensable for clearing knots and chips. Also when using Umpherston, Acme, or any similar type of beater, I have seen

a refiner pass 1000 lbs. of stuff per hour, the stuff being of an even length, free from knots or chips. When the refiner was off we were bothered with chips and irregular lengths of stuffs, especially with wood papers."

T describes the action of the refiner as being of a rubbing and clearing nature. This is to the point. "In making news or printings from wood pulp refiners can be used for stuff that has received very little treatment in the Hollander."

V remarks, "In the beater the stuff can be got to the right degree of wetness, and in the refiner can be brought to right length and fineness." He recommends the use of refiners where the appearance of the paper is a great consideration. He points out that the work of the refiner and the beater are complementary to one another.

CHAPTER X.

AGITATION AS AN AUXILIARY TO BLEACHING.

Agitation—Increased rapidity—Influence of air and sunshine—Increase of temperature—Theory of action.

QUESTION 10.—*Does rapid agitation assist bleaching? If so, why?*

B is rightly of opinion that it does, as agitation brings the fibres more quickly in contact with fresh supplies of the bleaching agent. This, perhaps, is the most important reason. He describes bleaching as a form of wet combustion, and draws a simile between the increased rapidity of bleaching through agitation and increased rate of combustion of coal by fanning a coal fire. I think this is a strict analogy. A fire burning in the usual way is analogous to a mass of pulp bleached without agitation, perhaps one might say that the process of poking a fire is analogous to stirring bleaching pulp, and the application of bellows to a wood fire is analogous to the application of a stirrer to a potcher of stuff containing bleach, although the rapidity of bleaching cannot be promoted to the extent that the rapidity of combustion of wood can be by imparting agitation.

D.—From my previous remarks it will be understood that exposure to a fresh supply of water is not the cause of more rapid bleaching, but rather the exposure to fresh supplies of oxygen.

E.—It must be admitted that after a certain amount of agitation the saving in time of bleaching as compared with the power expended, as in the case of stuff agitated in a poacher, for instance, would not warrant the agitation being continued: in fact, it might result in a dead loss from an economic point of view. But this is rather outside the question. In the bleaching of some stuffs, such as esparto, where the mass is kept in circulation, and where it is expedient to make the process as rapid and continuous

as possible, I venture to think there must be considerable saving of time effected, due to the fact of keeping the stuff in motion.

F looks at the question from a somewhat different aspect. He is evidently much in favour of agitation. "If the rags were not to travel the bleaching would not be half so effective." "Agitation seems to liberate the oxygen." This may be indirectly so, as the carbonic acid in the air which is brought into thorough contact with the bleach liquor undoubtedly has the power of liberating hypochlorous acid, $HClO$, which in its turn liberates the oxygen which bleaches the fibre. "By rapid agitation the fibres are broken up better." This depends upon the mode of agitation, and whether any breaking-in or beating is being conducted simultaneously with the bleaching.

G remarks: "It cannot produce any chemical action, though it will assist it." As will be seen hereafter, agitation not only accelerates the rapidity of the bleaching, but it also in a measure brings into play a somewhat different chemical reaction.

H remarks: "The more agitation the rags get, the more chance will the chlorine have of working its way into the interstices of the fibres." There is some truth in this, as apart from the mere chemical reaction when dealing with rags that are not broken in, the mechanical beating the rags receive during the agitation must beat the air out and cause the bleaching agent to penetrate more readily into the interstices of the fabric. This is apparently what **H** means.

I remarks "that very rapid agitation has a drawback by exposing more of the heated stuff to the air than if it were going slowly. This reduces the bleach, therefore slower bleaching action." If the agitation is promoted by an ordinary beater-roll, it necessarily churns a large amount of air into the stuff, and in a small measure causes some of the chlorine to pass off into the air. I think that it will be found, however, that this amount of chlorine is too small to affect the question from an economic point of view. But more of this hereafter. "The only way to make the stuff travel quickly is to have the engines light." But you can "agitate" thick stuff without making it "travel" quickly round the engine. "**I**" points out that by furnishing the stuff thin, in order to promote more rapid circulation, you diminish the strength of the bleach and, consequently, the rapidity of its action, and he gives an instance in support of this. This is quite true.

K remarks: "If the agitation is conducted for some time the temperature of the mass rises, and thereby hastens the

operations." Of course the temperature is rising from the very commencement, due to the rapid agitation, but as chemical reactions of this kind are more susceptible of increase of temperature at comparatively high temperatures than at low ones, every degree of rise, say, between 80° and 90° Fahr., produces a greater increase in the velocity of the chemical action than each degree of rise between 50° and 60° Fahr., consequently bleaching effect due to increased temperature is more marked after the "agitation is conducted for some time."

L.—"Yes, by stirring up the oxygen and making it more active." This is very crudely put, as the expression "stirring up" can hardly be applied to such an elusive and hypothetical substance as nascent oxygen, which is believed to be the actual bleaching agent. According to the chemical theory, this oxygen in the nascent or atomic condition would be a totally different substance from the molecular oxygen as we know it; moreover, nascent oxygen is no sooner brought into existence than it reacts with the fibre or substances in the fibre, producing the bleaching effect. It can hardly, therefore, be said to exist at all in the ordinary sense of the term, as it only forms a connecting link in a train of chemical reactions. "The whole of the surface of the fibre is some time or other brought in contact with the bleach."

M gives a reason for agitation which has not been advanced by any of the foregoing: "Yes, because it means exposing the stuff more to the air, the carbonic acid of which liberates the hypochlorous acid, the active bleaching agent." He then gives the equation, showing the decomposition of the calcium hypochlorite by the carbonic acid.

I was in hopes of seeing mention of the action of the carbonic acid in the other answers. The equation given is correct, but it would be better to introduce H_2O into it and to give hypochlorous acid as $HClO$ instead of the anhydride Cl_2O. The equation would, therefore, run thus—

$$^{*}\underset{\text{Bleach}}{CaCl_2O_2} \underset{\text{and}}{+} \underset{\text{carbonic gas and water}}{CO_2 + H_2O} \underset{\text{produce}}{=} \underset{\text{chalk}}{CaCO_3} \underset{\text{and}}{+} \underset{\text{hypochlorous acid.}}{2\ HClO.}$$

Of course the amount of carbonic acid in the air is small, but it is sufficient to accelerate the action during agitation. There is one important bleaching process founded on the influence of

* This equation is not strictly correct, but it is the best that students can give, unless they have a considerable knowledge of Chemistry. It is quite near enough for all practical purposes.

carbonic acid, viz. the Thompson process, in which an atmosphere containing a large amount of carbonic acid is brought in contact with the fabric moistened with bleaching powder solution. The action of bleach is very much intensified, and instead of calcium hypochlorite being the bleaching agent, hypochlorous acid does the work, which latter is much more active.

N considers that "the rapid agitation as in the circulating system bruising and brushing the stuff assists the action of the (bleach), and under the circumstances can be done quicker." The mechanical disintegration and brushing of the stuff is perhaps the least important factor in increasing the rate of bleaching.

Q remarks: "By the more constant opening out of the fibres to the action of the bleach, and by further cleansing the fibre from any remaining dirt or foreign body. This function must have its effect on the fibres, and make them a little more susceptible to the action of the bleach." It can hardly be claimed that any mechanical cleansing can be effected while the bleaching is actually going on, but extraneous matter and dirt, after the bleach has acted upon it, may become loosened and detached. This loosening may be assisted by mechanical agitation, but the dirt cannot be got away until the bleach is washed out.

R gives further evidence in support of agitation promoting bleaching. He says that it has been noticed that light furnished engines do bleach quicker. As previously pointed out, this mode of argument does not appear to throw much light on the subject. If the lighter furnished engine contained the same percentage strength of chlorine or solution, it would contain a higher proportion of chlorine to a given weight of dry fibre. This fact alone would account for more rapid bleaching effect, apart from any additional agitation that the thinner stuff may be capable of receiving. We must, therefore, pass over these remarks. **R** brings forward further evidence that contact with the air will assist the bleaching, and this I had hoped to have seen in other answers, especially from those who have studied chemistry. Air contains ozone and peroxide of hydrogen. "This ozone and peroxide of hydrogen, in being decomposed, form nascent oxygen, which alone is able to bleach, and, therefore, the rapid agitation will oftener bring the fibres in contact, and thus assist the bleaching." **R** goes further than this, for he also tells us that "The sun's rays are the principal promoter of this chemical action, but I am inclined to think that in an ordinary atmosphere much the same work goes on." There are several publications on this

point, to which I should be pleased to refer students if they would care to read them. The sun does bring about the formation of these substances, as far as we know directly through the actinic rays, and indirectly by promoting condensation and evaporation, which bring about electrical discharges, *i.e.* silent discharges, which in their turn bring about the formation of ozone. Ozone by itself is a powerful bleaching agent, and is likely to come into commercial use as such, if a cheap enough method can be devised for making it. Ozone, furthermore, accelerates the action of bleaching powder, and results in a saving of chlorine. The presence of either ozone or peroxide of hydrogen in the air lashed into the stuff by the action of the beater roll, must, in a measure, affect the rapidity as well as the economy of bleaching, but to what extent it is not easy to ascertain. The presence of direct sunlight in a bleachhouse must also assist the bleaching, and more so when the stuff is agitated, continually exposing to the sun's rays fresh layers of pulp.*

S.—"When bleaching esparto grass, especially Spanish grass, engines should be heavy, as light engines knot very easily." S in his answer is really discussing other questions, such as the thickness of the furnish. This should be studied from the point of view of the material itself, and not made subservient to the question of agitation. On this point I would refer him to my previous observations. S recommends agitating for one hour, allowing to rest for half an hour, then agitating for one hour, and resting half an hour, and so on, until the desired colour is obtained. I venture to suggest that in many mills this would hardly be practicable.

T remarks: "Yes, the more rapid the agitation the sooner the bleaching is effected, the action of chlorine is assisted by exposure to air and light." He has the happy knack of putting a good deal into a very few words, and although he does not show much sign of theoretical knowledge, his practical observations are often excellent. It would be better if he gave a little more time to his answers, and treated them at greater length.

* Ozone and hydrogen peroxide cannot *both* be present at the same time in the air, as they mutually decompose one another, with the formation of oxygen and water. Is it possible that the minute traces of ozone or hydrogen peroxide in the air have any appreciable effect on rags or other stuff in a poacher? Has any one yet proved the presence of ozone in the atmosphere? The ordinary test papers are acted on in the same manner both by oxides of nitrogen (always formed by disruptive electrical discharges) and hydrogen peroxide.—Note by Dr. H. P. Stevens.

V remarks that "Rapid agitation of the pulp results in a more even bleach being obtained." He looks at it from the point of view of overheating being avoided when live steam is used. "In cases where acids are used to assist the bleaching, the acid is more evenly distributed, producing a more evenly bleached pulp."

Note on B's Answer.

By bleaching wood pulp under certain conditions we have recently observed a very substantial rise of temperature which takes place immediately the unbleached material is mixed with the bleach solution. This rise of temperature is in some cases as much as 10° F. We hope to be able to actually measure the units of heat evolved per gram of available chlorine consumed.

CHAPTER XI.

THE HEATING OF "STUFF" FOR THE PAPER MACHINE.

Effect on fibres—Water from wire—Knotters—Sizing—Shrinkage and felting.

QUESTION 11.—*What is the effect of heating the stuff as it passes on to the paper machine, and why should this produce a change in its behaviour on the machine?*

B has given a very fair answer indeed. Heating, he says, "is resorted to in the case of 'wet' stuff papers, such as banks, loans, etc., and all papers where the speed of the machine is affected. In hand-made paper the stuff is generally kept 'flesh' hot, in order to get the water through the mould quicker." The immediate effect (see question) upon the stuff, due to heating, is to cause the water to pass through more readily. In hand-made paper the shake can be adjusted to suit the rate of flow of water, or the rate of the flow of water can be adjusted to suit the shake and other conditions by adjusting the temperature. **B** realizes that the effect of heating is to dehydrate the fibres or to counteract the "wetness." It not only influences the rate of flow at the wet end, but also the suction as well as the water removed at the press rolls.

As **B** justly concludes, it influences the drying over the cylinders not so much from the fact that the web is slightly warm but that it has been dehydrated. It must not be forgotten that the stuff is hottest where the steam is first applied, but as the heat is gradually radiating the stuff cools down, and becomes cooler and cooler as it passes along the machine. "Heat applied at this stage of the process also interferes with colours and shades, and is one of the causes of wrong shades when matching a sample."

"Machinemen do not use the thermometer, as they get to

know by practice the amount of steam to use." In my opinion it is a great mistake to do without the thermometer at any time, however much a machineman may have confidence in himself and his own judgment. **B** and other students would do well to gain as much knowledge as they can on dehydration of soluble reverted cellulose in the various publications by Cross and Bevan and the author. Also to read articles appearing in the PAPERMAKER, such as the "Function of Water in the Production of a Web of Paper," and the author's publications before the Franklin Institute which bear on the influence of heat and moisture on the dehydration of gelatinous cellulose. **B** would do well after reading the question to dot down any headings on a slip of paper, and from these headings to construct his answer. All writers would find this method beneficial. He remarks, "I take it some examiners are broad-minded individuals." An examiner has a very difficult duty to perform, and it is certainly necessary that he should be as broad-minded as possible, and put as liberal an interpretation on the answers as he possibly can. The object of these test questions, however, is primarily not to *examine* but to *help* students to guide themselves in building up their knowledge, and in forming conclusions in their everyday work. It is impossible to *teach*, in the ordinary sense of the word, but it is hoped that it will assist all workers to use the paper mill as an object-lesson, and to gain a proper understanding of the general principles on which the practice of papermaking is, and should be, based. When they are accustomed to this mode of procedure they will in time be able to advance their work without so much outside assistance.

C says the "effect of heating the stuff is to make it work freely. I should think it affects engine-sizing in same way." Heat is very likely to influence the engine-sizing, but in order to ascertain what influence it might have, it would be necessary to conduct trials at different temperatures. Trials of this sort would be very useful and instructive.

D says, "that heating the stuff is mostly done where the machines are provided with short wires, and where wet stuff or heavy papers are worked. It is sometimes difficult to get the stuff sufficiently dry at the couch roll, so that the stuff does not pick up at the press. Heating the stuff a little will sometimes remedy this by allowing the water to be more readily drawn out at the suction boxes." Most of this answer is very practical, but ends up by attributing the effect to a wrong cause. "The reason is that water, when heated, expands, and the density being reduced, it can pass more easily through the meshes of the

wire." The effect of expansion or reduction in density would have the opposite effect. The water becoming lighter would not fall so readily through the meshes. The water becoming more *fluid* as it is heated might influence its flow to some extent, but the *prima causa* is the influence which the heat exerts upon the fibres in rendering them more easily deprived of water, and also more capable of allowing water to pass through their mass. A very simple experiment will illustrate this. Take two filter-papers of equal size and place each by itself in a funnel; fill one with cold water and the other with boiling water, and note the difference in the rate of flow.

E remarks that heated stuff does not "carry its water so well when passing over the machine. It also weakens the stuff, taking all the backbone out of it." Overheating will produce a very poor appearance in the sheet; it will often become soft and flabby and lacking in strength and appearance. **E** realizes the danger that may result from overheating. It is undoubtedly owing to this, that some papermakers object to heating at all unless it is absolutely necessary.

F.—"Stuff passes through the strainers better. Too much heat takes the 'feel out of the paper.'" He appears to think that the heat is sufficient to soften the water, and that this may influence the question. The temperature is not high enough to produce such an effect. "When the fibres are cold they are sticky and lie closely together, so that the water does not drain away so readily. Heating counteracts this effect."

G.—Heating the stuff "shows the dirt up;" it is possible that the vibration due to the steam entering the stuff may dislodge particles of dirt which may also be introduced by means of the live steam.

H thinks that through heating "you lose much of the size and loading." It is not known how far heating would account for additional loss in this way, but it is a very good suggestion, and appears to be one of the best practical reasons that could be brought against the practice of heating the stuff.

I remarks: "If the temperature is too high the small particles of starch will swell up, and consequently the finished sheet of paper will not have such a good rattle." In order to swell or burst starch granules, it is necessary to raise the temperature to a point far higher than that to which the stuff is heated on the machine. There may, however, be a little local heating at the point where the live steam enters, but this could hardly in any case account for much difference in the quality of

the paper. In almost all cases the starch must be a minor cause.

J.—Heating "assists the strainers to open the knots caused by the agitators travelling too quickly, especially with grass stuff."

K.—"The first effect (of heating) is to throw up a good deal of froth, owing to the liberation of carbonic acid gas from the stuff." This is an interesting subject, and becomes more so when we study the chemical changes which take place in the engine or in the chest. When alum reacts with carbonate of soda, sulphate of soda is formed, and alumina deposited. In strong solutions an effervescence will be produced by the evolution of carbonic acid gas. In weaker solutions, such as exist in the chest, the carbonic acid gas remains dissolved in the water. The alum also reacts with hard waters containing bicarbonate of lime, setting free carbonic acid, which furthermore remains dissolved in the water. The water in the chest is therefore more or less charged with carbonic acid gas, which is easily driven off by introducing steam, due partly to the rise in the temperature, but largely to the general disturbance of the liquid effected by the steam jet. Heat "enables the machineman when working long stuff to use more water to form the sheet." In this respect it can be made to answer the same purpose as lowering the breast roll. Heated stuff "does not stand the sizing test so well as that which is made in the cold, especially if gelatine is the sizing agent." In the latter case the reason is evident. Heating produces free stuff, and free stuff produces an absorbent paper, which would be more difficult to render ink-proof with gelatine. "Warm liquids flow more quickly than cold ones." This, as previously explained, is a minor cause.

L.—"If the paper be a blue-tinted one, the shade will fade a little." He thinks that the heating will cause the fibres to curl, thus giving them less felting power. "Such papers have a dull or dead appearance."

M gives a practical instance where it may be expedient to heat the stuff. "When esparto stuff is too short in fibre, and too wet, it is sometimes apt to stick at the press rolls, especially when working on a short wire, where it is not possible to extract so much water as when working on a long wire. In such cases the machineman first shuts off as much water as possible, and if this does not stop the sticking he resorts to heating the stuff." "Sometimes stuff is heated to cure cockling, which is due to too rapid drying at the cylinders, as it enables the machineman to

press harder at the press rolls." The web containing less water can be dried more gradually on the cylinder and the cockling avoided.

N.—"Heated stuff has not the same tendency to crush at the couch roll." **N** considers that overheating causes slime and dirt, and "acts on the engine size and starch."

Q.—Very wet stuff, such as that produced from tarpaulins, is particularly troublesome, and the difficulty may be overcome by heating the stuff. Stuff that has stood over the week-end can be run over the machine much freer after heating.

R.—Heating renders fibres more "inflexible." This is a happy expression. With wet stuff the fibres are pliable, and by heating they become inflexible, and consequently they do not felt in the same way. **R** considers that the use of steam is not to be recommended, except when the stuff sticks so badly at the press rolls that it becomes unworkable. He considers that the best sheet of paper is got when no steam is used.

It is gratifying to note that the writers generally have a better grasp of the influence of water upon the fibres than they had on the questions set at the commencement. Of course wet stuff means fibres expanded or distended by the prolonged action and contact with water. Wet stuff is also due to the formation of hydrated cellulose, seen under the microscope as an indefinite jelly-like mass. Any heat applied tends to undo this by shrinking this up and making it harder. Heating the stuff would tend to make a sheet which would shrink less whilst drying, in consequence of the ultimate fibres themselves being partially shrunk before they are felted together. We can therefore in a measure control the shrinkage of the web by regulating the temperature of the stuff.

S states that thin papers do not require heat and that thick papers do—*i.e.* papers from 40 lbs. Demy and upwards.

T.—"Heating enables the machineman to get the pulp spread more easily."

U.—"Heating the stuff has the effect of breaking down by the force of the steam jet all the small knots, etc., formed by the agitators." The breaking down of knots by the mechanical action of a steam jet is totally different to that of acting on the stuff by raising the temperature. It is obvious that the latter effect is what we particularly have to consider.

V considers that the water leaves the fibres more easily after heating because the latter are rendered stiffer. The reason that the paper has less rattle when the stuff is heated is not due to the

softening of the fibre, but rather to *the hardening or stiffening of the fibres before they become felted together. If the fibres are felted together whilst they are in a pliable and sticky condition the paper has more rattle.*

In some of the above instances quotations have been made from papers without comments. This has been chiefly for the edification of readers.

CHAPTER XII.

COMPARATIVE RESULTS OF QUADRUPLE AND OPEN EFFECT EVAPORATION.*

Comparative merits of systems—Yaryan—Porion—Table of costs—Causticising—Rotary furnace.

THE recovery of soda from spent lye, no matter by what system of evaporation and incineration, requires the greatest care and attention where mills such as those using esparto are situated in close proximity to fine running streams, and into which the discharge of a substance such as spent soda lye would almost verge on criminality. We have mills so placed in which the quantity of esparto used will not warrant the erection of a modern recovery plant, and where it must suffice to erect a modified system of evaporation and incineration irrespective of economical results so long as river pollution can be prevented. Such systems as these will not compare with the now more modern type of evaporator with detached incinerator, but nevertheless a system of open evaporation and incineration such as the Porion requires every consideration. In this contribution I intend going into the comparative results obtained in two systems :—The Porion, as representing an open system, and the quadruple Yaryan as a system working on the vacuum principle.

One of the most important systems of evaporation now used in the recovery of soda on a large scale is the Yaryan, with an incinerator such as the rotary or reversible roaster. Before going into details, it may be as well perhaps to describe the principle on which this evaporator is wrought, as also a few details on construction. The principle may be expressed as :—The utilization of the latent heat of vapour given off by the liquor undergoing

* Notes written by a reader in answer to Question 12.

evaporation in one vessel under a certain pressure, to effect a further evaporation upon the same liquor in another vessel, and consequently at a lower temperature. The maintenance of an increased vacuum in each successive separator lowers the temperature still further, and as the temperature of this vapour is less than that of the steam first used, the boiling point of the liquid in each of the vessels is reduced. For every 1 lb. of high pressure steam used we have a corresponding evaporation of 1 lb. of vapour out of the liquor in the first effect. This vapour in turn evaporates another pound of vapour in the second effect. In successive operations in the third and fourth vessels we have work done correspondingly.

The efficiency of any evaporator of this type in respect to the amount of fuel consumed depends on the evaporative power of the boiler which supplies the steam. It will readily be seen then, that for every pound of water evaporated in the boiler, the multiple effect will do 2 lbs., the triple effect 3 lbs., and the quadruple effect 4 lbs. This is purely theoretical, as owing to unavoidable losses such results are hardly ever obtained in practice. As a matter of fact, it is an impossibility to get the more than $3\frac{1}{4}$ times useful effect out of steam—that is, in the case of a quadruple effect—the boiler doing 8 lbs., the evaporator ought to do 26 lbs.

The quadruple effect (Yaryan) consists of four vessels of tube formation built of steel plate and well riveted together. In each of these vessels we have an arrangement of tubes 3 in. in diameter in coil formation. A coil consists of 60 lineal feet, and it may consist of one or half a dozen tubes. Sixty feet of tube represents 45 square feet of heating surface. Water evaporated per square foot of surface varies a great deal, according to the nature of the liquor, and whether the surfaces are of copper or iron. For the former, a fair average with cleanish liquor would be about 100 gallons per coil, *i.e.* 1000 lbs. for 45 square feet. Soda lye 100 gallons treated, or 80 gallons of water evaporated per coil, may be taken as a fair average. On such data, knowing the quantity of lye to be treated, a fair estimation of the size of an evaporator may be obtained.

In conjunction with each effect we have a separator fitted internally with baffle plates, which separates the partially concentrated liquor from the vapours, after evaporation has been effected in the "effects." Each vessel has its own regulating valve. This valve is nothing more than a plate with perforations corresponding with the first tubes of each coil, but of much less diameter, and works on the face of the tubes, and by means of a screw can be opened or closed or otherwise regulated so as to admit the liquor

into the tubes in the finest film possible. Each separator is fitted with a gauge which shows the height of liquor, as the absence of this points to the fact that vapours are passing into the coils, where they would otherwise pass into the shell of the succeeding vessel, or, if the separator be too full, the liquor may pass along with the vapour into the shell of the same vessel. With a view to economy, each vessel is provided with a superheater of similar construction to the vessels, so that the condensed vapour from the corresponding shell may be utilized as a heating medium to the liquor in its course to the first effect. The vacuum is maintained in the separators and shells combined by means of an air pump and condenser; the other accessories being the feed pump, the tail pump, which pumps the concentrated liquor to the storage tank at the incinerator, and the drip pump, which removes the condensed vapour from the vessels and discharges it into suitable storage tanks. Contenting ourselves with this short description of the component parts of the evaporator, we may now look into the system on which it is worked. The liquor is led into a tank connected up to a feed pump, which discharges it through the superheaters into the coils of the first vessel. By means of the regulating valve, which is partially closed, thereby causing resistance against the pump, the liquor is forced into the tubes in a fine film or spray. High pressure is admitted to the shell of the effect, causing the liquor to boil, and after the liquor has traversed the coils it discharges itself into the separator, where the partially concentrated liquor separates from the vapour, the former passing into the coils of the second effect and the latter into the shell. Being under the influence of a slight vacuum, the boiling point of the liquor is slightly reduced, and the evaporation goes on in exactly the same manner in the second effect as it was carried out in the first. Similar operations are carried out in the third and fourth effects, each effect having a higher vacuum than the one preceding, corresponding to the gradual fall in the temperature of the vapours. The last separator is connected up to the tail or discharge pump, which pumps the concentrated liquor to the storage tank of the incinerator. The remaining vapours left in the separator are drawn off by the vacuum pump, and finally condensed by means of a jet or surface condenser. The drip passing from the shells is taken through the superheaters, and is finally discharged into suitable storage tanks.

Having briefly described the principles of the working of a machine, we might consider, in the first instance, a few of the points to be allowed for in ordering such an evaporator:—

1st. In ordering a Yaryan, the greatest care ought to be exercised in stating the quantity of the liquor to be treated, making allowance for any extension in the mill with the view of greater production, and which means increasing the amount of raw material to be treated.

2nd. The hardness of the water ought to be estimated, showing what percentage of lime and magnesia salts it contains. Some mills might find the surface of the metal covered with a hard film of scale, which is often difficult to remove. In such cases the evaporation in the vessels naturally goes back, and increased steam pressure has to be used to get the desired results.

3rd. You cannot depend on having a steady boiler pressure at all times, more especially where the plant may have the service of one boiler. This, of course, may be obviated by having an assisting connection from the mill battery. There are cases in the winter time when, in frosty weather, one has nothing but cold liquor to start up with in the early part of the week, which means a pull on the boiler.

4th. There may be occasions when you have an extra supply of washing water, more than you bargained for, caused perhaps by some of the attendants opening a wrong valve. Such things have happened. In all cases I think the evaporator ought to be made to cope with at least 25 per cent. more volume than the ordinary quantity. It is quite easy, when the liquor is steady in density, temperature and volume, to reduce the steam pressure in the first effect.

The Porion evaporator is entirely of brick construction, banded together with heavy cast-iron plates, which are held close to the brickwork by means of tie rods. The evaporating chamber is of a tunnel construction, varying in length from 35 to 45 feet, by 5 feet wide, by 5 feet 6 inches high, to the centre of the arch. In this chamber are arranged two sets of fanners, which are made to revolve at a speed of from 280 to 300 revolutions. These may be driven direct from a vertical engine or from any convenient shaft from which the desired speed can be got. The combustion chamber varies in length from 18 to 22 feet long, by 9 feet broad, by 11 feet high. In this chamber the erection of a series of baffle walls is necessary so as to break the flame in its course to the evaporating chamber, thereby aiding the combustion of the bye-products from the incinerating hearth. The roasting hearth is from 16 to 20 feet long, by 13 to 16 feet wide, the rise on the arch from the hearth being 1 foot 9 inches to 2 feet. The hearth is generally divided into two by a division wall running the entire

length, making the width 6 feet by 7 feet 6 inches, the arrangement causing each hearth to be fired and worked alternately. Each hearth has its own furnace, measuring 5 feet long by 3 feet broad. In several cases we have a furnace situated between the firegrate and the hearth which is fired with coke, the idea being to consume the smoke from the coal before it comes in contact with the concentrated liquor on the hearth. At the extremity of the evaporating chamber is placed the chimney which gives the necessary draught to the evaporator, modified by dampers; but in many cases where convenient a flue is made and connected to the mill chimney. Conveniently arranged at the discharge end of the evaporating chamber is placed a malleable or cast-iron tank which acts as a receiver for the concentrated liquor from which the roasting hearth is supplied. The weak liquor enters the evaporating chamber, which, owing to a slight fall on the hearth of the chamber, flows towards the discharge end, where there are arranged a series of slices of sufficient depth to maintain a certain volume of lye in the chamber; at the same time they regulate the dip of the fan. The lye in its course towards the discharge end of the chamber comes in contact with the fan, which, owing to its high speed, dashes it into a very fine spray. In this fine state it comes in contact with the flame from the combustion chamber, causing evaporation. The lye, now in a concentrated form, discharges itself into a tank, and after sufficient is gathered it is run on to the incinerating hearth. A strong fire is now brought in contact with it, further evaporation takes place, and after a time ignition. The batch or charge, as it is called, is worked until it becomes quite ash-like in appearance, drawn into barrows and put in heaps, where after a time it chars itself into a white ash.

The whole products of combustion pass into the combustion chamber, where they are consumed. So great may be the heat in this chamber that the baffle firebrick walls are completely burned down in a few months. This forms the heaviest part of the upkeep of the Porion, and in many mills this part of the construction is entirely done away with, the products of combustion passing direct to the evaporating chamber.

For comparative results we will take a mill using 200 tons of esparto weekly. From the quantity of esparto treated we would probably have a volume of strong or weak lye combined of 158,000 gallons, at a density of from 6° to 6½° Twad., at a temperature of 135° Fahr. Treating this quantity in a quadruple effect Yaryan alone, without the aid of a high-pressure calandria, in addition to the effects a volume of concentrated liquor equal to

19,150 gallons at a density of 45° Twad. at 135° to 138° Fahr. Taking the quantity of lye treated in a week of 125 working hours, we would treat on an average 1260 gallons hourly. Out of this quantity we would have to evaporate 1110 gallons of water per week. The heating surface required to evaporate same would be $\frac{1110 \times 45}{80}$ or 624 square feet, or equivalent to, as it would be erected, a 12-coil machine. We will base our results on a Lancashire boiler doing an evaporation of water from and at 212° Fahr., and taking the heat required to convert 1 lb. of water at 212° Fahr. into steam at atmospheric pressure as 966, the total expenditure of heat in the evaporation of 8 lbs. would be—

$$966 \times 8 = 7728 \text{ T.U.}$$

To heat, then, 158,000 gallons from 135° Fahr. to 212° Fahr., requires

$$\frac{158{,}000\ (212-135)}{7728} = 15{,}742 \text{ lbs.} = 7 \text{ tons } 0 \text{ cwts. } 2 \text{ lbs. fuel.}$$

Water evaporated,

$$1{,}580{,}000 \text{ lbs.} - 191{,}500 \text{ lbs.} = 1{,}388{,}500 \text{ lbs.}$$

$$\frac{1{,}388{,}500 \times 966}{7728} = 173{,}562 \div \text{ by four vessels}$$

$$= 43{,}390 \text{ lbs. of fuel per vessel};$$

but as this is only theoretical efficiency, and, as I said before, we obtained only $3\frac{1}{4}$ times or 80 per cent. practically, the probable consumption would not be less than 52,068 lbs. = 23 tons 5 cwts. 3 qrs. To drive pumps, etc., you cannot reckon on less than 112 lbs. per hour, or 6 tons 5 cwts. per week. The data we now have are—

	tons	cwts.	qrs.
To heat 158,000 gallons of lye to 212° requires coal equal to	7	0	2
To evaporate 138,850 gallons of lye from 212° requires coal equal to	23	5	3
Fuel for pumps	6	5	0
Total fuel consumed	36	11	1

From the total amount of liquor treated we would recover at least 34 tons of ash testing 48 per cent. Na_2O, so practically our evaporation has cost us 1 ton $1\frac{1}{2}$ cwts. of fuel per 1 ton of ash.

In the incineration part of the process with the reverberatory furnace a fair average of the amount of fuel used would be 4 cwts. per ton of ash recovered, and with the rotary 3 cwts. Hence we may estimate the average total amount of fuel required in the production of 34 tons of ash at 41 to 42 tons, or 1 ton of ash for 1 ton 5 cwts. of coal. In the working of the rotary much saving can be effected by carrying the flame from the furnace direct to the tubes of a water-tube boiler with an auxiliary fire grate. In the reverberatory roaster such heat is passed underneath a pan placed on the top of the flue which serves as the receptacle for the concentrated liquor from the Yaryan, the viscous mass being brought to boiling point with simultaneous further concentration before entering the incinerating hearth. To effect a concentration equal to that obtained when working in conjunction with a rotary, the concentrated liquor is pumped into a calandria of vertical formation, the steam for concentrating purposes being supplied direct from the boiler. This effects a further concentration and brings the concentrated liquor to boiling point. I have not estimated the amount of fuel required for this part of the work, as I consider whatever heat is expended in this extra evaporation is no more than the heat obtained in the flue of the reverberatory furnace which is used for concentrating purposes. Still, at the same time, any one might say : What value are we to put on the flame or heat given out by the rotary which corresponds practically with the heat used in the Porion for carrying out the evaporation in the chamber? I have known cases when the concentrated liquor was sufficient in volume to keep a fierce flame in the furnace and reduce the quantity of coal burnt at the boiler—so that when the amount of water evaporated divided by the fuel consumed was estimated, we had an evaporation of 12 lbs. of water per lb. of coal; still, we could not count on such a result being obtained on all occasions, as in many cases we have the combustion up and down, and when it is down then the carrying of that heat which is partially moistened on the tubes of the boiler does more harm than good. Still, it is a point worth investigation. As to the drips from Yaryan, these ought to be utilized in places where direct steam is involved.

1st. In the causticising department. To convert 34 tons of recovered ash, testing 48 per cent. available soda suitable for boiling purposes, we would require a volume of 102,000 gallons of water. The drips from the second, third, and fourth vessels would practically supply this. From the quantity of liquor treated we should probably have a volume of 97,195 gallons at

a temperature of 175° Fahr. To meet the little deficiency we would have 41,655 gallons at a temperature of 130° Fahr., the discharge from the vacuum pumps, leaving a surplus of 36,850 gallons. The steam condensed in the first effect in heating and evaporating the liquor should be pumped direct back into the boiler, the feed pump being connected direct to the vessel. That volume being equivalent to 54,320 gallons at a temperature corresponding with the pressure existing in the shell of the first effect, which is, as a rule, 20 to 25 lbs., we should require an auxiliary feed to make up the deficiency as used by the pumps, etc., which would approximately amount to 11,200 gallons. The balance of water is used for washing out the tubes, which ought to be done at least every twenty-four hours. Having such a large volume of hot distilled water at our disposal for causticising and other purposes, naturally lessens the cost as far as coal consumption is concerned. Where the volume of water required for causticising has to be heated from 60° Fahr. to 212°, one can readily see the great saving effected in having water at a temperature of 170° to 175°. On one side we would have—

$$\frac{1,020,000\ (212-60)}{7728} = 20,062 \text{ lbs. of fuel} = 8 \text{ tons } 19 \text{ cwts.,}$$

on the other side we would have—

$$\frac{1,020,000\ (212-175)}{7728} = 2 \text{ tons } 3\tfrac{1}{2} \text{ cwts.,}$$

or a saving of fully $6\frac{3}{4}$ tons of fuel on the causticising of 34 tons of ash per week. Taking the condensed steam from the shell of the first effect back into the boiler practically dispenses with an economizer, as the temperature of the feed-water is 250° to 260°, but still, if there was an economizer, a further saving would be effected in raising the temperature of that water to a corresponding temperature to that existing in the steam boiler.

Looking now to the incinerating point of the question, *i.e. The Rotary.* Owing to the quantity of fuel used in roasting the concentrated liquor being so infinitesimal, the ash as discharged from the rotary is practically free from contamination with sulphur; the same may be said of the reverberatory furnace. One great drawback with the rotary is, I think, that the combustion of the organic matter is so perfect that very little combustible matter is left in the black ash as discharged from the hopper, and after being put down in heaps the heat gradually leaves it. We have then to consider the treatment of black ash containing 42 per cent. of available soda. The treatment is one of lixiviation

in separate tanks, the liquor containing the dissolved soda being run by gravitation to the causticisers. After the refuse carbon has been properly washed, it is thrown out of the sieves and carted away. In time this refuse becomes a nuisance. The lye prepared from such ash has to be treated very carefully, as it is very liable to carry with it finely divided particles of carbonaceous matter, which is a very serious question where the manufacture of fine papers are involved. Still, if the ash could be made to calcine itself white, there should be no difficulty in getting an ash testing 52 to 54 per cent. available soda. The reverberatory, I think, has the advantage over the rotary, inasmuch as the batch of ash is worked by hand, and sufficient organic matter can be left in the ash to effect a complete combustion. Such ash as is produced by the reverberatory can be used direct in the causticisers, being placed in a cage perforated with holes through which hot water is allowed to percolate. Where manual labour is involved the rotary is the saver, two men only—one night and one day—being employed. In the reverberatory you would require four men—two night and two day—with assistance when drawing a batch, probably from the man attending the Yaryan. We may say, then, that we save the wages of two men, but the extra trouble caused by having so much extra work in the causticising department, where extra hands will be required, swallows up whatever saving has been gained in the incineration.

The Porion. As the results obtained with this evaporator and incinerator depend upon the efficiency of the latter, it results, in the first place, that the liquor (feed) must be of such a density that you can always rely on a fair volume of concentrated liquid. Naturally enough, where weak lyes are treated it means the consumption of a large quantity of coal before you can get sufficient concentrated lye to aid the evaporation in the chamber. The subsequent washing of esparto by means of the washing water has greatly aided the result of the Porion. The treatment of such weak lyes requires time—the diminution of the feed has to be considered—until the liquor is sufficiently concentrated to incinerate without difficulty and produce the necessary heat in the evaporating chamber. Comparing this part of the process with the quadruple, the method there employed in overcoming the difficulty consists of increasing the pressure of the steam on the first effect without diminishing the quantity of feed. You have then the means of maintaining your percentage recovery, but not without the expenditure of an extra quantity of fuel. To evaporate such a volume of lye as we have considered in discussing

the system of quadruple effect evaporation would require two Porions of such dimensions as I have stated. The probable total consumption of fuel in the evaporation and incineration of this volume of lye would be about 46 tons.

Taking the density of the lye at $6\frac{1}{2}°$ Twad. and 135° Fahr., we might expect its density at the normal temperature to be about $10\frac{1}{2}°$ Twad. The approximate weight of this volume of lye, 158,000 gallons at the normal temperature, would be 1,704,030 lbs. If the recovered ash be fairly well incinerated, we may count on the following proportions :—Ash recovered testing 42 per cent. Na_2O = 86,912 lbs.; combustible organic matter, 89,112 lbs.; water evaporated = 1,528,006 lbs. Taking the quantity of coal consumed as 46 tons, the evaporation would correspond to 14·18 lbs. of water per lb. of fuel consumed, or taking the fuel and organic matter combined, an evaporation equal to 8 lbs. of water per 1 lb. of combustible. Little more can be said regarding the working results of the Porion, and we now sum up our conclusion in the following remarks :—Taking all in all, the first place undoubtedly goes to a system working in the vacuum principle, with an incinerator of the Rotary type or *Brown's Roaster*. The conditions favourable to such a system are :—1st. A perfect means of regulating the treatment of the volume of feed liquor—the conditions of this treatment can be altered without the least difficulty, the control of steam being one of the essentials. This can be effected by taking the steam direct from the mill battery, or by the installation of special boilers to provide the necessary supply of steam for the evaporator. 2nd. The large volume of distilled water at the mill's disposal which would otherwise involve the use of direct steam. 3rd. In all systems where the liquor is brought in contact with burning coal, the sulphur from the latter is retained in the liquor, forming sulphur compounds. On the other hand, in the vacuum system, the evaporation being effected by means of steam—and out of contact with the flame and vapours from the burning, these sulphur compounds are not formed during concentration of the liquor. The wear and tear is at a minimum. Generally speaking, all that would be required would be occasional renewal of jointing. Proper care, as I have said, ought to be taken with the feed lye, inasmuch as the feed liquor must be passed through a fine wire cloth, to remove the finely divided fibrous matter held in suspension ; if this is not done a film will deposit on the inside of tubes, which will probably result in loss of the economy effected by the system. Taking the roasters, rotary and reversible, the point of view to

be taken may be expressed somewhat as follows :—It is paper manufacture we are engaged in, we wish to recover the spent soda from the lye with as little cost as possible, but still, we must not suffer anything which will deteriorate the quality of the manufactured article. The rotary furnace, as far as my experience admits, is unequalled in the saving of manual labour, maintenance, and the utilization of the heat from the furnace, but its drawback seems to be the quality of ash recovered. As I have said, the ash contains on an average 42 per cent. of soda, it is floury, and most of the finely divided particles are liable to suspension. You may take the first treatment—first lixiviation —as extra. The refuse black carbonaceous matter not only becomes a nuisance, but you have all the extra labour in carting. More settling capacity is required, and really, to have the caustic lye as it ought to be, it should be passed through a very fine sieve, or preferably a sand filter. Taking the reversible roaster, we have more tear and wear ; but, on the other hand, the men at the roaster can prepare their batch, leaving as much combustible as it requires to complete the incineration in the heaps consuming itself to a fine crystalline or rocky mass. In this case we have a direct treatment in the causticising pots—little or no refuse is formed—and we have a lye perfectly free from black tick.

The Porion—this form of evaporation is open to objection, inasmuch as the whole of the sulphur in the fuel finds its way into the recovered soda, forming sulphites, part of which is decomposed in the furnaces with the formation of sulphides, sulphates, and other sulphur compounds. All vapours pass to the chimney and are lost, consequently in causticising we have to use cold water, whereas in multiple effect hot water could be made use of with decided advantage. One must observe that a Porion is constantly undergoing repairs, as in the case of the incinerating hearth with the piers supporting the arch of the roaster ; and the same may be said of the firebox. The combustion chamber seems to give most trouble ; here fire works havoc, and, as a rule, it has to be more or less repaired every year.

It is rather difficult to form an estimate of the cost of maintenance, as opportunities are snatched to effect small repairs.

Author's Note.—The above chapter can only be regarded in the light of somewhat fragmentary notes, and furthermore the practice therein described cannot be regarded as up to date. Many improvements have since been introduced, but it serves to show the conditions still prevailing in some mills, and at the same time furnishes some useful data.

CHAPTER XIII.

HOW TO PREVENT ELECTRIFICATION OF PAPER ON THE MACHINE.

Probable causes—Theories—Means of prevention—Printers' difficulties—Patents.

QUESTION 13.—*How do you account for paper becoming electrified during manufacture; and what steps would you take to prevent it?*

B's answer we give, because there are many points in it that require discussion. The answer is very fair indeed, but on some matters he shows a want of theoretical knowledge.

"The paper becomes electrified by friction as it passes through the machine calendering rolls.

"This may be prevented either by 'chilling' (*i.e.* running cold water through) the last stack of rolls and the reeling drum.

"By suspending copper brushes immediately over the web just before it is reeled.

"Or by keeping the rolls as bright as possible.

"Possibly, by gearing the rolls instead of driving them from one another.

"The electricity developed cannot be attributed to friction alone, as there is pressure, heat, etc., to be considered.

"It is only in hard-dried papers where electricity is retained. More friction is produced between the driving and first-driven rolls in each stack than in the others, and also by the last stack of rolls being driven slightly faster than the preceding ones.

"Much of the electricity developed is conducted to earth by the metal rolls and by the copper brushes (generally pieces of copper machine wire nailed to a piece of wood suspended along the width of the web, which it very lightly touches), but dry paper,

being a (so-called) non-conductor, generally retains some, despite the use of these conductors.

"Some of the objections to electricity in paper are: The trouble caused to printers: the static electricity is conducted away by the ink, which it disturbs; the effect on expansion when moistened; the 'hanging' of the sheets together when sorted.

"Hard-dried, roughly-finished paper will become electrified by the friction caused by merely gliding over the top rolls of still stacks of calendering rolls. (The underside, then, by-the-by, is slightly smoother.)

"In super-calender stacks compressed cotton and paper rolls are sometimes substituted for metal, but these do not affect the question of electricity much. These are more liable to be excited by electricity, but there is, on the other hand, not so much friction produced."

C says: "Heat causing friction between cylinder and paper." Heat may be regarded in two senses as a cause of electrification, but cannot be regarded as the cause of friction. Electricity is produced, under certain conditions, by evaporation. Heat bringing about evaporation of moisture from the paper may set up electrification. It must be realized, also, that the electrification of paper is largely due to its being an insulator. Paper, when moist, is a conductor of electricity; but in proportion as it becomes dry, it becomes an insulator.

If space would permit, I should like to have given figures for the electrical resistance of paper under various degrees of moisture, the results of which I have by me, and which were carried out for a special investigation. When this is better understood by the aid of such figures it becomes easier to realize why the web becomes electrified. The drier the paper the greater the resistance to the flow of electricity, and consequently the greater its power of holding a so-called static charge. When paper is bone-dried by heat it becomes an excellent insulator, and if excited by friction, or any other way that will produce electricity, it is capable of being highly electrified. "The electrification can be got rid of by passing the paper over a cold cylinder." This appears to be the more general way of overcoming the difficulty. This may be due to two causes. The cooling of the paper would rapidly enable it to assume its atmospheric moisture. In doing so it becomes more of a conductor and the static charge leaks away. It is also a well-known fact that condensation produces electric current of the opposite kind to that produced by evaporation. It is possible, therefore, that

the condensation due to the paper taking up its atmospheric moisture on cooling would tend to charge the paper with the opposite sign, and so neutralize the electricity already existing in the paper, which came there as the result of evaporation. But this point is somewhat speculative. **C** is right in his assertion that "having the cylinders too hot will tend to make the paper more electrified."

D.—"Paper also becomes electrified at the super-calenders. If you heat a sheet of newspaper and cut it into strips and then rub it smartly with the hands it becomes electrified, and the ends fly apart." The reason of this is that an electric charge either of − or + electricity is self-repellent. Each strip being charged with electricity of the same sign does its best to get away from the other, and consequently the strips fly apart. **D** mentions that in order to discharge the current "a long copper bar with spikes across the machine and under the web is placed at a point after the paper leaves the calenders."

F considers that the question is a very important one, and that electricity is a source of very great trouble and annoyance, and is the cause of a lot of glazed paper being broken, the sheets adhering so firmly to one another, that they are only removed with very great difficulty. He realizes the fact that the presence of rosin is an important factor, and tends to increase the trouble. It is a well-known fact that the friction of felt, especially when it is dry, rubbing against rosin will produce frictional electricity. Rosin, furthermore, may assist in the electrification by rendering the paper more perfect in its insulation. The so-called frictional electric machines are machines for bringing dissimilar substances into intimate contact, and then drawing apart the particles that have touched each other, becoming electrified in the process. If the two bodies that are rubbed together are both good conductors, they will not become strongly electrified, but, if one is a good insulator, we have practically the conditions of a frictional electric machine. The paper machine, therefore, is a frictional electric machine, as it conforms to these conditions. **F** points out that "care must be taken to have the paper as hard dried as possible to stand the glazing." Where hard drying is therefore essential, he recommends cooling the paper as much as possible before reaching the reeler, and the use of a brass chain just dragging on the paper to assist in the removal of the electric charge. "A moist room is better than a dry one." "In a news-mill sprinkle plenty of water on the paper before it is reeled up."

G speaks of the friction of the dry felts, especially when they are woollen felts, and the various sources of friction along the machine which are likely to result in electrification. It must be remembered, however, that unless the felts and the paper are practically dry, friction will not produce any electrification, or possibly the electricity produced will be conducted away by the moist felt or paper as fast as it is formed. "A damping roll either before or after the calenders will prevent a good deal of electrification."

H.—The electricity is very noticeable when the paper is dried rapidly, but less so when gradually dried.

I remarks: "I have been informed that if the stuff is heated at the wet end when liquid, it electrifies more quickly than when it is cold." It is difficult to see what this has to do with the question. It may have some influence. Thus, if heating the stuff altered the character of the surface of the paper, when friction came to be applied, it might produce a greater electrification; but in making such a statement reasons should be given, as otherwise it is impossible for one to judge whether there is any significance in this remark.

K.—"The friction acts upon the rosin in the paper in the same way as when a piece of amber is rubbed, and the latent electricity is excited." A copper rod or wire is sometimes stretched from one side of the calender to the other, to conduct the charge away.

L.—Electricity in paper at the reel end is due to the paper passing over the straightening roll in a hot, dry state, thereby generating electricity by friction.

M realizes that the difficulty is greatest when the atmosphere is frosty and dry. This is a very true remark. In damp atmospheres the difficulty is nothing like so marked, but in dry and frosty climates the nuisance due to electrification is largely increased. It is a well-known fact that you can do nothing with an ordinary frictional machine in a damp room, but when the air is very dry the electric charge can be obtained with the greatest ease. **M** recommends the following remedy:—"A copper wire suspended over the paper after coming from final nip, end fixed on to the frame, or, better, let into water, will conduct away the electricity."

N remarks: "The better the quality the more electricity." It is impossible for one to judge what is here meant. A tub-sized paper, for instance, would be a higher quality than one containing rosin size, and yet the liability to electrification would be

greater, in most cases, in the latter than in the former on account of the presence of rosin. I judge from his remarks that he considers a paper containing more clay to be less likely to electrification, but not because it is non-conducting. As already explained, the greater the non-conducting power the greater the electrification. The clay would probably be a better conductor than the rosin, but it might also influence the electrification, by affecting the friction in some way. A trough filled with water, from which pieces of copper reach to surface of the paper, is suggested as a remedy.

R's answer we print in full: "Water is an excellent conductor, and to this reason I attribute the fact that papers finished by the new Water-doctor process do not develop electricity to such an extent. New rolls are worse than old ones. I believe before steam was introduced for heating the rolls, paper-makers were not troubled to the same extent as now. I have seen a copper wire passed over the sheet of paper in front of the rolls to conduct the electricity away, and I think the system of cooling by means of copper or brass cylinders through which cold water passes is very effective."

Heat makes paper an almost perfect insulator by depriving it of all its moisture, but for other reasons many other substances which are good insulators when cold become bad insulators when hot. A good many of the students do not realize the fact that a substance to hold a static charge does not require to be a conductor; in fact, it must be either an insulator or be insulated in some way. The fact of paper when hot being a good insulator enables it to hold the electrification imparted to it by friction. If it were not so we should not have this trouble.

U's answer contains some practical remarks. Is he right, however, in stating that the whole of the electrification is found at the calenders and smoothing rolls?

"For paper to become electrified in the course of manufacture, heat or friction is required. The electrification of paper is all done at the super and friction calenders or smoothing rolls, and is caused by the paper entering the calenders in a warm condition, as when overdried. The calenders themselves often become heated, or, as in a number of cases, they are heated by steam so as to produce a better surface, and considerable electrification results. I have also noticed considerable electrification on starting up on a Monday morning (when everything is cold) for one or two hours. This is due to the *friction* resulting from the rust, etc., on the calenders. To overcome this electrification the

calenders must be cool and clean, and no steam should be used. The paper must also be cool. This may be accomplished by avoiding over-drying the paper or by damping the paper with water before it enters the calenders, which of course tends to cool the paper. Calenders may be kept cool by keeping a stream of water running through them, most calender bowls being hollow. The friction due to dirt, etc., may be overcome by cleaning the calenders before starting up with soda, ash liquor, or with common petroleum oil. The electricity may be conducted away by a copper rod or old strip of machine wire placed about one inch from the bottom bowl and connected to earth."

V's answer is printed below for the general information of readers. It is difficult to find an analogy between the cylinders and the generating plate of an electrophorus :—

"Paper may become electrified through several causes :—

"1. Electricity produced by the friction of the paper on the drying cylinders. Friction caused by the slipping which takes place during the contraction of the web while drying, and the friction of the felts and bowls upon the paper whilst hot.

"2. Electricity generated during the evaporation of the water from the moist paper.

"Of these, the first is the chief cause, and there can be little doubt but that the presence of rosin in the paper adds not a little to the ease with which the web becomes electrified. Indeed, it seems to me that this is a factor which influences the electrification to a considerable degree, as I have noticed that the trouble at the reels due to electricity is more acute when making hard-sized papers than when running soft-sized. It seems to me that the sheet while passing over the cylinders can be compared to the generating plate of the electrophorus, and the reel to a condenser. Of course the paper must be very dry, as if it be damp no noticeable electrification takes place, and one way to cure the trouble would be to dry the papers only so far as to leave them a little damp if their value or the use to which they would be put afterwards would warrant this.

"The electricity is generally removed from the paper just before reeling and after passing the calenders. It can be effected in several ways. Some run a small copper roller on the surface of the paper. The roll contains water in many instances. Another way is to have a copper bar with pointed pieces of metal fixed at right angles to it, the bar being placed either above or below the web before reeling. The bar is connected to damp earth. Some mills have a copper wire stretched across the

machine, with pieces hanging down on to the paper at intervals. This is practically the same thing as the copper bar with points. I have often seen sparks 4 ins. to 6 ins. long obtained from the reel of a machine running paper made from sulphite well beaten, and often wondered whether the electricity could be utilized."

E's answers for the most part cover the same ground as many of the others. "The reason for paper becoming electrified on the machine is on account of its passing over heated cylinders and friction produced."

Q remarks, "To prevent the electrification of paper as much as possible, it must be run as damp as circumstances (colour, pulp, etc.) will allow. Calenders should have a continuous stream of cold water through them, and all pressure eased as much as possible."

S.—It will, no doubt, be understood from what has already been said, that the friction of the beater roll on the stuff has nothing whatever to do with the electrification of the web of paper. "High machine-finished papers have always a lot of electricity in them." Does S think it is fair to say that they "always" do? His suggestions for overcoming the difficulty are: "A perforated steam pipe the breadth of the machine with the steam playing on the paper." "A copper wire the width of the machine is nailed to a piece of wood and held within an inch or two of the paper as it goes to the reel."

To give an adequate answer to this question requires a certain amount of knowledge of what is known as frictional electricity, and if any readers require to gain a sufficient understanding of this subject they could not do better than read about the first 70 pages of Silvanus Thompson's "Elementary Lessons in Electricity and Magnetism," published by Macmillan & Co. Any other kind of electrical knowledge is not really wanted, but if a grasp can be obtained of this the thing will be seen in quite a new light. There seems to be a general idea that anything in order to be electrified must be a conductor, but the very essence of the production of frictional electricity is that one or other of the excited substances should be an insulator. If you tear asunder a strong, dry piece of paper in the dark you can often see an electric spark. This is the result of the friction of the fibres one against the other. We may take it that, whatever other causes there may be exciting electrification along a web of paper, the primary cause is friction on the dry paper. Supposing that one surface of the paper is rubbed or pressed in such a way as to produce a charge of one sign on its surface, there will be an equal charge of opposite sign developed on the material with which the

paper was rubbed. These two charges remain after the paper and other material are separated from one another, but as the paper is a non-conductor the charge remains upon it even although the material was a conductor and its charge had escaped to earth.

Franklin described the electricity excited by rubbing a glass rod with silk as positive electricity; that produced on resinous bodies by friction with wool or fur, negative electricity. On the drying cylinders we sometimes have bone-dry paper containing rosin coming in contact with a dry felt. We have here the wool and the rosin in contact with one another. Pictet found "the degree of electrification produced by rubbing two surfaces together to be independent of the pressure and of the size of the surface in contact, but dependent upon the materials and on the velocity with which they moved over one another. Rolling contact and sliding friction produced equal effects." We must not assume, therefore, that increased pressure of rolls produces electrification, nor are we justified in assuming that it is necessary to have one surface sliding over another as with friction rolls, as we are informed on the best possible authority that rolling contact and sliding friction produce equal effects. We shall be right in inferring, therefore, that the greater the speed through the calenders the greater the electrification, but that additional pressure on the stack of calenders will not increase the electrification. "Evaporation of liquids is often accompanied by electrification, the liquid and the vapour assuming opposite states, though apparently only when the surface is in agitation." "If a card be torn asunder in the dark, sparks are seen; and the separated portions, when tested with an electroscope, will be found to be electrical. The linen faced with paper used in making strong envelopes and for paper collars shows this very well." When the air of the machine room is very free from moisture and dust, the paper is much more likely to be electrified. Dust assists in preventing electrification almost as readily as moisture. In damp weather it is a matter of very great uncertainty whether electrification will take place or not, unless the paper is being hard dried. One student suggested that the action is similar to that of the electrophorus. But this mode of action cannot account for the electrification of paper. The action of the electrophorus is summed up by Silvanus Thompson in the following words: "A conductor, if touched while under the influence of a charged body, acquires thereby a charge of opposite sign." In order to imitate the action of the eloctrophorus it is necessary that the paper should first be electrified. This mode of action might

account for a charge of opposite sign on a conductor, such as a roll in contact with paper, but this charge would have to be induced by a charge already existing on the web. The paper would have to be excited before such action could take place. It is no use here attempting to go deeper into this subject, as it is too much out of the line of papermaking. Those who wish to study the subject can easily do so, and when they have once mastered the main principles they can apply their knowledge in a practical way to the paper machine, and will find such rudimentary knowledge, if properly applied, of real practical value. It is suggested that after having read the portion of the book abovementioned, that a few of the elementary experiments be tried as illustrated in the book. A student could then explore along the web of the paper machine by means of an electroscope (which he can either make for himself from two pith balls or obtain for a very small sum), and he will be able to ascertain very readily when the electrification commences, where it reaches its maximum and where it falls off to nothing, how long the paper remains electrified, and whether the electricity is plus or minus. If he studies the question when favourable opportunities present themselves, he will be able to see how the composition of the paper and the drying affect the electrification. If also he has a wet and dry bulb thermometer with which he takes readings at the time of his experiments, he will be able to see to what extent the atmospheric conditions affect the electrification. Now, all this is very interesting from a scientific point of view, but where is its practical utility? This question has been raised because it has a practical bearing. We all know that the electrification is at times a considerable nuisance; it wastes time, gives trouble, produces broke, and often after leaving the machine during subsequent glazing and printing it may occasion considerable trouble. When you know what the electrification is caused by, how and where it exists, and under what circumstances it is produced, you will be able to find a more effective remedy. It will probably be found that in a large number of cases the remedy applied is not the best and most expeditious one. It may be found necessary to alter the position of the brushes. It may be found most expedient to apply one particular remedy to one class of paper and another to another.

No book on electricity will give you much clue to the conductivity of paper. A word about this will be a help to you. When paper is wet it is not only a conductor, but also an electrolyte. Wet paper conducts even more readily than water. When

it gets nearly to ordinary air-dryness it becomes a little resistant. When it is about air-dry it may be regarded as an indifferent insulator. As the moisture is further removed, its insulating qualities rapidly increase until it reaches bone-dryness, when it may be regarded as an excellent insulator. It cannot, however, remain bone-dry for long in an ordinary atmosphere. Immediately the heat of the web is removed it rapidly begins to assimilate moisture, and in doing so it, of course, rapidly loses its insulating qualities. When it is bone-dry it has its greatest power of electrification, because it is a high insulator, and does not permit the charge of electricity to leak away. As before mentioned, the amount of rosin in the paper adds to its power of electrification. Rosin, furthermore, adds to the insulating properties of paper. The insulating and electrical properties of paper are probably best known by the post-office authorities, who make use of it for insulating their wires. They know very well that paper is a fair insulator when the covered wires are kept dry by being placed in tubes; but when once the covering comes in contact with damp air, insulation breaks down.

A difference exists between leading a current away by actual contact, such as by trailing a chain on the surface of the paper, and discharging the current away from the surface of the paper by bringing a conductor with metallic spikes across the web and within an inch or two of its surface. The former removes the current by conducting it, the latter induces a current of opposite sign in the spiked conductor until it gets so strong as to cause discharge to take place across the intervening space. This discharge is the result of the plus and minus charges coming together, and so neutralizing one another. Both methods have their advantages and disadvantages. The latter, I should think, would be more generally useful. To understand this better, read page 49 of the book above mentioned. The peculiar sensation when coming near to the reel of an electrified paper is due in a large measure to what is known as a brush discharge. It produces an electric wind. The air in immediate contact with the fine fibres of the paper becomes electrified and repelled, and the current is thereby gradually and slowly discharged through the medium of the atmosphere. The hairs on the back of the hand if held close to a reel assist in bringing about this silent discharge and promoting this so-called electric wind. Dr. Stevens informs me that he has seen a current of air blown against the web on the calender rolls adopted as a means of dissipating the electric charge on the surface of the paper. He tells

me this method is adopted in one of the most up-to-date news mills in Germany, and its efficacy may be attributed to the particles of dust in the air becoming charged, and dissipating the electricity. Recently a method of removing electrical charges from paper has been devised by W. H. Chapman, an American engineer, which is said to be working satisfactorily, and which may be thus described : It consists mainly of a transformer supplied with current from an alternating lighting system. There is a primary coil of 200 or 360 turns of coarse wire, and a secondary coil consisting of 40,000 to 50,000 turns of very fine wire. When the voltage of the primary is 110, the voltage of the secondary becomes about 22,000 volts. A non-inductive resistance coil limits the output of the secondary coil, and thus obviates the dangers of this very high voltage. A conductor extends across the cylinder at the point of the sheet delivery, which is supplied with an alternating current of high voltage from the transformer. The primary coil of the transformer may be short-circuited by means of a suitable switch. The action of the current is governed by a switch with four segments, so that more or less current may be passed through the primary current of the transformer, but the resistance coil is always in and cannot be cut out, and thus the resistance is sufficiently great to prevent a dangerous amount of current from passing at any time. The alternating current is thus transformed to a high voltage current, and this, transmitted through a wire, neutralizes the static electricity of the paper which automatically selects and becomes neutralized by the charge of opposite polarity in the alternating charge.

The inventor thus describes the problem he had to solve: "Practical experience during the last two years with the alternating current as applied to this problem has proved conclusively that this is the only natural and adequate method of dealing with these unstable forces and conditions, and that a stable and neutral condition can thus be forced in an absolutely complete and effective manner. The alternating current, as its name implies, has in it both kinds, positive and negative, and in the presence of such a current the charges on the paper become their own destroyers, under the law of like and unlike. Under this law the charges on the paper, whether positive or negative, whether in patches or uniform over the whole sheet, become self-selective and draw out of the alternating current the kind and quantity required exactly to neutralize them. The air, being an insulator, would under ordinary conditions prevent any interchange of charges between the paper and a conductor carrying the alternating current, so that

it is necessary to provide a medium for the conveyance of these charges across the intervening space. This medium is easily supplied by ionized air produced by the action of points, attached either directly to the alternating conductor or to pieces of metal in its vicinity. When the hand is placed before a point so located, a breeze is distinctly felt, which represents a stream of electrified air particles or ions, as they are called, which act as carriers, and convey charges across spaces of several inches and at a rapid rate, so that it is by no means necessary to have any material object touching the paper to effect its complete neutralization. As a matter of fact, the inductor bars, as they are called in this system, are usually located so that the paper will pass by them at a distance of a couple of inches, and it is usual to have only one of these inductor bars on a printing press and have it located as near the delivery end as possible, so that the paper does not have an opportunity to pick up any more charges by friction or bending or pressure before being laid on the pile, where it will then lie perfectly smooth and free from the sheet below it."

CHAPTER XIV.

TRANSPARENCY OF PAPERS.

Reasons for—Influences—Effects of Composition—Glazing—Mineral—Beating—Modes of testing—Comparisons.

QUESTION 14.—*Why are some papers more transparent than others? Give instances as well as reasons.*

B gives a very fair answer indeed, which is given in full below. No attempt is here made to discuss the weak points, as they will be largely dealt with in the remarks made at the end of the chapter.

"Difference in treatment of the same material.

"(*a*) Beating.—By prolonging beating, which renders fibres more highly hydrated and, therefore, more transparent (the more cellulose is in a viscous condition, the better it transmits light).

"(*b*) Machine.—By working wet. By calendering.

"The use of naturally transparent substances. With different materials, giving them the same treatment in every way, the original transparency of the ultimate fibres are in the following order: Chemical wood, straw, esparto, cotton, linen, hemp.

"An instance of difference in transparency in papers made with the same material and practically the same treatment, but with different quantities of loading, can readily be quoted in the case of a cheap Bible paper containing 25 per cent. of loading and one containing 15 per cent. The latter is the more transparent. The difference in bulk, or rather thickness (same size and weight), does not equal the opacity of the extra loading in the former. With regard to finish, take a sheet of fairly rough-surfaced antique. If the surface is brought in a line with the eye, individual fibres will be seen sticking up, and also in little groups which proceed from the mottled parts or where in the

making, stuff is thickest. In looking through the same sheet these little groups constitute the most opaque portions. Tear the sheet in two pieces and pass one piece through the calender rolls. Then compare it with the rough piece. It is, of course, now much more transparent, and, as a rule, the most opaque parts have now become the most transparent, for these were the thickest parts, and consequently received the greatest pressure.

"We may assume that the rough surface 'splits' the light, and that when light waves of equal length are directed against a rough surface they do not meet with an even resistance. Some waves are 'hit' by the 'ridges.' Others go farther into the smoother parts. In each case the waves may be partly transmitted, but the uneven dispersal of the waves which are not absorbed causes them to strike the eye unevenly. The effect is that with ordinary papers we get the impression of whiteness; if with the so-called coloured papers, the impression produced is that caused by whichever colour wave is unabsorbed by the substance in the paper. Or, every little fibre sticking up on the surface throws its shadow on the surface round it, and this may be that although in calendering the paper is rendered more dense, the fact that the actual surfaces are rendered smoother prevents the obstruction of the light on the surfaces themselves.

"In special cases—for instance, parchmentized papers—where the structure of the fibres have been altered (*i.e.* by H_2SO_4) and then pressed, without leaving an opaque deposit, and in tracing papers, where the natural transparency of the Canada balsam, turps or oil come into force, the cause of transmission of light is obvious.

"There is, of course, more to be said on the subject, but the chief principles at work in producing transparent papers are: The nearer stuff is got to a known transparent body; the more of a transparent body used; and the smoother the surface."

C states that sizing the paper will also make a difference. We shall be able to understand the reason of this better later on.

D states: "A highly bleached paper is more transparant than a low bleached: a Spanish grass more than African. Grass that has been properly cooked gives a better and more transparent sheet than grass that has not been so well boiled." The reason of this can, we think, be very briefly explained. Pure cellulose, from whatever source, is fundamentally transparent, its opacity being only apparent from the property which the cells have of reflecting the light in every possible direction. This we have already discussed in connection with a previous question. When,

however, the cellulose is not pure, as in the case of mechanical wood, or in that of badly cooked fibres, the cell walls contain lignin and other substances that are fundamentally opaque. In proportion as the cell walls contain these substances, so will the paper be more opaque.

E remarks: "If the paper is required to be transparent it is advisable perhaps not to use loading, but should loading be used, mineral white is preferable to china clay, because it is much purer and whiter, and therefore would not give that pronounced opaque yellow tinge so often seen in papers loaded entirely with china clay." He considers the bleaching is the more important factor of the two.

F.—"An all linen stock produces a very transparent paper, because the fibres from linen are very straight ones." "The more a paper is beaten the more transparent it becomes." He goes on to explain how it is that pure cullulose is in itself transparent and the apparent opacity is due to the physical structure of the fibres. He furthermore mentions the influence of bulking in its relation to the question of transparency.

G.—"A paper made from wood is more transparent than a rag paper, and a paper made from cotton alone is very opaque." He should have stated here whether he meant mechanical or chemical wood, and he should go further by saying whether he meant sulphate, sulphite, or soda wood, and whether it is bleached or unbleached, because these considerations make all the difference.

H lays special emphasis on the time of beating. "A superfine made from soft cottons and beaten about four hours will be transparent, and a blotting paper made from the same material and beaten about one hour will be opaque." "Pearl hardening is more transparent than china clay, and loaded papers more opaque than unloaded, as the fibres are more transparent than the loading." As far as it goes, this mode of treating the subject is good.

I.—"Papers often differ from one another in transparency on account of the composition of loading, as in papers of the same substance and in each case bleached to the same extent. The stuff has to be taken into the case as well. The raw material before it is in a suitable state for addition to the beater has to go through a process, and during the operations, the kind of treatment it receives has a considerable influence on the transparency of the fibres." He recommends the use of soda wood for cheap envelope papers to make them opaque; and he furthermore states that sulphite wood gives a more transparent paper than soda. As minerals for transparent papers he recommends the use of

satinite and pearl hardening. The following remark is interesting: "If two sheets of the same kind of paper are taken from the same machine, one being overdried, whilst the other has excess of moisture in it, the former will be more opaque than the latter." We do not gather whether he means to imply that these papers remain permanently different in their transparencies when they come to the air-state. This is the real practical question.

K gives an instance of the influence of beating:—"The longer we beat the stuff the wetter it becomes, as it takes on a gelatinous nature, which, if not counteracted by loading or pigments, absorbs or transmits the light. For example, an E.S. writing paper with, say, 14 per cent. ash is more transparent than a litho paper made with practically the same furnish and the same amount of residue." This is a good practical statement, but rather spoilt by the word "absorbs" having been introduced.

"Because they are better boiled or bleached and have all the incrusting substances removed. This is more noticeable in wood papers, and comparing two wood papers of equal loading, the better bleached is more transparent, besides being whiter. If the paper be carefully drawn out in the beating process, and well closed on the machine, it will be more transparent than if cut up and rendered free, like blottings, for instance."

M has dealt with this subject in quite a different manner to the rest. His final remarks are very good, and have not been touched on by the majority. More will be said on some of the general points discussed in this answer, when concluding.

Answer.—"The reasons why some papers are more transparent than others are almost innumerable, and can be traced back from practically the finished sheet to the first stages of the manufacture.

"The principal factors influencing the transparency are as follows (order of process of manufacture):—

1. Preparation of the half-stuff.
2. Quality of furnish.
3. Treatment in beater.
4. Treatment on machine wire.
5. Surface of paper.
6. Substance of paper.

"1. In the preliminary treatment of the half-stuff, the boiling and washing affect the transparency of the paper indirectly. Hard boiling or insufficiently washed stuff will not come to as good a colour as when it is properly boiled and washed, and a high

bleached stuff makes a more transparent sheet than low bleached. Therefore the way the stuff has been boiled and washed will have its due effect on the transparency of the sheet.

"2. If it were possible to have all the factors equal, with the exception of quality of fibre used, then the transparency would *roughly* take the following order:—

a. Linen and straw.
b. Sulphite wood.
c. Esparto, cotton, soda wood.
d. Jute, manilla, hemp.
e. Mechanical wood pulp.

"This is not intended to be a hard-and-fast classification, as it is largely a matter of opinion; and the market grades of the different raw materials will considerably affect it. For instance, Spanish esparto grass is generally more transparent than Oran, etc.

"Quantity and quality of loading added, also influences transparency.

"Terra alba is more transparent than clay.

"Starch helps to make the stuff 'greasy' and 'wet,' and therefore increases transparency.

"3. The shorter the stuff the more transparent, the longer the more 'cloudy' and opaque. Instance—stuff generally kept long for envelope papers in order to increase opacity.

"The length of fibre being the same, 'free' stuff will make a more opaque sheet than 'wet' stuff. This is owing to the water parting with the fibres quickly, leaving them all irregular and 'standing up on end' on the wire. (Filter paper good example of opacity, partly due to 'free' stuff.) On the other hand, 'wet' stuff will retain more loading than 'free' stuff, and if the loading used is of a lower transparency than the rest of furnish, the sheet will be rendered more opaque.

"4. Although the stuff may be well milled for a good close sheet, it may have a 'wild,' broken (sometimes called a 'hungry') look, which diminishes the transparency; this is due to the way the stuff is worked on the wire. The sheet is not properly 'closed;' that is, the water is not far enough forward on the wire. This may be remedied by shutting the first pump box a little more. On the other hand, if the water is too far forward it will have a watery 'run' (local name, 'nirled') appearance, which also diminishes transparency, remedied by opening the first box a little more.

"A long wire will facilitate the making of a close and

transparent sheet better than a short wire, because the fibres are under the influence of the shake for a longer time, and get more flatly and closely interwoven.

"5. Generally speaking, the higher the surface the more transparent the sheet—compare a thin paper before and after super-calendering. This will be partly due to the decrease in bulk, but the dampness before calendering considerably affects it. Note the increased transparency when a paper comes away too damp from drying cylinders, becoming blackened and transparent after passing through calender rolls.

"Transparency varies indirectly as the substance—compare transparency of a 10-lb. Demy to a 30-lb. Demy."

N's short answer is well to the point. He recommends keeping the stuff warm and working it a little wet. He states that the stuff must be well boiled and bleached, and recommends satinite as a loading material.

Q states it as being necessary to have the stuff long, sound and well matured, and bleached and ground thoroughly.

R's paper contains one or two points which deserve to be noticed, and therefore it is given in full below, but he has gone wrong on one fundamental point. Pure cellulose is not opaque. If devoid of structure it would be absolutely transparent. Well-treated cotton and linen may be considered to be equally pure cellulose. The reason raw cotton gives so much more opaque a paper than linen is due to the structure of the fibre, and is in no way a question of purity. The question of broke adding to the opacity of a paper is a very important one. The more thorough the treatment in the kollergang the better. The broke fills up the interstices between the other fibres, such as sulphite wood. Straw has a wonderful effect in this way.

Answer.—"There are many reasons why some papers are more transparent than others, and this is a question admitting of a few controversial points. A good deal depends on the material the paper is made from and the constitution of the cellulose. Pure cellulose is opaque, and therefore papers made from cotton, which is the purest of the celluloses used in paper manufacture, will produce a more opaque paper than, say, linen. Papers also made from sulphite have a more transparent appearance than esparto papers, owing to the bright reflecting nature of the former. The amount and kind of loading carried has also a marked effect. China clay, which is the principal loading material now used, is of a dull characteristic in comparison with the bright and more transparent feature of P. hardening. An increase in the

transparency of paper may be got through using kollergang broke. Given the same materials for different engines and using a quantity of the broke thus prepared in one of them, it will enable the stuff to carry more of the loading and result in a more opaque sheet, owing to the fineness of the broke and the way in which it settles between the pores of the fibres. Mechanical wood also, owing to its opaque nature and its good *filling* qualities, will counteract the transparency of paper made from sulphite wood. The treatment of the stuff in the beaters has a very marked effect on the quality of paper turned out, and also the treatment in the washer and poacher. The cleaner the stuff is washed and the higher the degree of whiteness to which it is brought in bleaching will help to produce a whiter paper. If the fibres are left intact in the beater and simply brushed out, they will result in a more transparent sheet. The kind of sizing material used also affects the question, animal size tending to make papers more opaque than rosin size. If the fibres are too long and free they require more water to felt them together, resulting in a greater loss of loading and sizing material, and thus add to the transparency characteristic of long fibres in making the spaces between them more apparent. It will thus be seen that the degree of transparency can be increased or otherwise by the quality of the stuff run into the chests. A finer engine let down among such stuff as I have mentioned will have a marked effect. An unsized paper also might be said to be more opaque, as the absence of the size permits of the fibres being better felted. The rosin size, although it may settle between the fibres, owing to its clear nature does not render the sheet more opaque."

S's remarks are very good, but they only deal with one portion of the question. "If your stuff is not well bleached you cannot get a transparent paper. I have seen paper made out of the same raw materials (grass and wood) with one lot especially well bleached. The stuff that was well bleached made a far more transparent paper. Sulphite wood helps to make a paper look transparent."

U realizes that linen is more transparent than other fibres in consequence of its structure. He also realizes the effect which the bulking has upon the question of transparency, and the difference between complete fibres and cut fibres in this respect. "Finish also makes a sheet far more transparent, particularly if long-fibred stuff and no loading is used, as the pressure to which the paper is subjected flattens out the fibres and fills up the interstices of the paper, thus closing the paper. This may be

seen by comparing paper made out of the same stuff before calendering and after calendering, bulk being equal, of course, in both cases." Is it to be inferred that the comparison is made on sheets of equal thickness or on the same sheet, comparing sheets before and after calendering? In the latter case we should not be comparing papers of equal bulk or thickness. The above remarks require a certain amount of qualification. The character of the surface imparted to the paper would affect the question considerably. Supposing you plate-glaze a paper and crush it, you certainly would not get the same result as regards transparency as if you super-calendered it, or as if you friction-glazed it on one surface only. Each of these papers would be differently affected as regards the question of transparency. Some kinds of glazing may be said to affect only the surface of the paper and not the interior. Plate-glazing may be said to affect the whole of the fibres. This, however, is too wide a question to be discussed here, and might well form the subject of another inquiry on some future occasion.

V's answer will add to the general stock of knowledge. His remarks about the mode of precipitation of the clay as affecting the question of transparency should be carefully thought over:—

Answer.—"The transparency of a paper depends upon several things.

(1) The amount of loading it contains.
(2) The kind of material employed.
(3) The treatment that the material undergoes in the beater.

"(1) It is fairly obvious that given two papers of the same composition as regards the fibres, but containing different proportions of loading, the one containing the most loading will be the more opaque, since the loading material itself may be considered as an opaque body. But the manner in which the loading is added affects the question. Sulphate of lime and calcium silicate may be added in the same manner as clay is generally added to the beater; but they may be also added or produced *in situ* by precipitation in the beater, in the latter case by causing sodium silicate and calcium chloride to react with one another. When the loading is added in this manner it is deposited on the fibre in a more finely divided state, and more effectively than in the ordinary way.

"Consequently, a paper thus loaded will be more opaque than

one loaded with the same chemical substance, but not precipitated in the beater.

"(2) The kind of material employed is, perhaps, one of the most important factors affecting the opacity of the sheet. Chemical wood pulps are all more transparent than cotton and rag papers, or jute papers, and—to take an extreme instance—than mechanical wood pulp.

"Here, again, sulphate pulp is more opaque than sulphite or soda. Bleached pulps more transparent than half-bleached pulps or unbleached pulp. Stuff made from old rags is less transparent than stuff from new rags.

"Mechanical pulp stands by itself; it is the most opaque of paper-making fibres (if it can be classed as a fibre), since it consists of wood with all the lignine matters just as it is found. Mechanical pulp made from the fir species is more transparent than that made from the pine species.

"(3) The treatment in the beater has also an important bearing on the question, and I think the chief factor. Stuff beaten 'wet' is more transparent than stuff beaten 'free.' Wet stuff has the property of forming an amorphous-looking sheet, and, as you remarked in commenting in Chapter V., that 'as a sheet of paper approaches a sheet of amorphous cellulose the more transparent it becomes,' one would conclude that viscose sizing tends to make the finished paper more transparent than it would be if sized with ordinary resin size.

"From the above conditions under which paper may be made, it is not difficult to understand why semi-transparent papers, as Banks and imitation parchments, are made from sulphite pulps beaten wet."

W's answer is somewhat confusing. "A paper made with all clear furnish and beaten fairly fine will be more transparent than the same beaten long and with the addition of a lot of broke and loading." He must not conclude from this that the long stuff gives a more opaque paper. The fact is that the broke and loading give the paper its opacity, and the long stuff is really serving to hold the mineral in suspension. If you were to leave out the broke and loading and merely compare the long stuff with the short stuff, you would probably find that, other things being equal, the long stuff would be the more transparent of the two.

To gain the necessary knowledge of the principles of optics, the reader could not do better than read the little book by A. H. Church on "Colour" (Cassell and Co.), also the little

book on "Colour Measurement and Mixture," by Capt. Abney, published by the Society for Promoting Christian Knowledge; but if you find even these two books too much for you to understand, you need not be discouraged, because although they are of very great value to a proper understanding of the subject, you can advance your knowledge considerably without them. There are one or two references in Church's book to the subject of paper. "When the rays of parallel light from the sun strike upon a rough, that is, an unpolished surface, say, of a piece of white paper, they are incident at all imaginable angles, with minute surfaces of the hollows and ridges which make up the reflecting substance, and such of them as are reflected obey the law, but are reflected in a countless number of different directions." This reflection of light in a countless number of different directions by the small fibres which compose the paper is the real cause both of the whiteness and opacity of papers. The greater these countless reflections the greater the opacity—the less the transparency. "The numerous small reflections which occur from and between the surfaces of the felted fibres in a piece of white paper may be greatly lessened by wetting or oiling the paper, when it becomes less opaque, and at the same time greyer and clearer; to this cause the transparency of tracing paper and tracing cloth is due."

"Bodies are said to be transparent when they permit light to pass so freely as to allow objects to be perfectly discerned through them."

It is by no means the best way of testing the transparency of paper to hold it up to the light. Of course, if we hold two papers up to the light, the one which appears the lighter of the two is the more transparent. What we want, however, is some simple mode of expressing the relative transparencies of different papers, and some simple and rapid way of making the tests. I will briefly describe the method which I have made use of for this purpose. It is simple and does not require any deep scientific knowledge, and I think you would all have no difficulty in making use of it.

Take a piece of white opaque paper printed in black with block letters. If you take two papers, one of which is transparent and the other opaque, the letters will be more easily read through the transparent than the opaque paper. This method of comparison is of course different to holding paper up to the light. In the method I am describing the light has to pass through the paper and illuminate it sufficiently so that the background is discernible. The light has to pass twice through the paper, first

to illuminate the background, and back again from the background to the eye. Now, suppose I take a number of papers of the same composition exactly, but of different weights per ream. Suppose, for the sake of argument, they are fairly thin and transparent papers. It is merely necessary to fold each a sufficient number of times so that it just renders the background invisible. Let us assume that A requires to be folded five times, B seven, and C eight. The one which is folded the greatest number of times is the most transparent, and relatively speaking we may compare the transparencies of these papers by stating the number of folds. The relative transparencies of these papers would therefore be five, seven, and eight respectively.

Now, suppose we take papers of different materials but of equal thickness, and desire to know their relative transparencies. We take a case in point. A is a linen bank, and B is a sheet of tracing paper of equal thickness. We have to fold A five times and B nine times before we obliterate the image at the back. We are able to state that, thickness for thickness, the transparency of A is to B as five is to nine. If we desire another comparison, we can take papers of different compositions but of equal weights (Demy). Now, of course it does not follow at all that these papers will bulk equally, but a stationer may require to substitute one paper for another at so many lbs. Demy. He may require a greater opacity. Now, we must assume again that these papers are fairly thin. A requires to be folded twice and B three times. From this we conclude that, weight for weight, the transparency of A is to B as two is to three.

Now we come to a further mode of treating the subject, and one which will enable you to come to very useful and definite conclusions from a papermaker's standpoint, and throw a lot of light on the question we have been discussing. We have, for the sake of example, a number of papers of different compositions, but made under known conditions. Let us assume that we wish to determine the influence of china clay on the question of opacity in an esparto paper. We know the ashes of the different papers; from this we can calculate the percentage proportions of esparto and clay. It is not necessary that these papers should be of equal thickness. We fold each of them in turn and place them over the background as before, and then, by means of a micrometer, we measure the thickness of each paper necessary to extinguish the background. The one which measures the thickest is, of course, the one which is most transparent, and the one which measures the thinnest is the least transparent, thickness for

thickness with the others. The micrometer readings, expressed either in thousandths of an inch or in millimetres, will express the relative transparencies of these different papers, thickness for thickness; and by comparing the compositions with these papers it will be very easy to arrive quickly at some definite conclusion. The same *modus operandi* can be used with regard to other mixtures and compositions. If the work is always conducted in a light room, but not in direct sunlight, one series of operations can be compared with the other on this basis. Such figures would undoubtedly be of great value in some mills where the question of transparency and opacity is of considerable moment.

CHAPTER XV.

THE "LIFE" OF MACHINE WIRES.

Effects of chemicals—Rate of speed—Output—Modes of cleaning—Putting on new wire—Adjustment—Antichlor—Free acid—Alum.

QUESTION 15.—*What influences the "life" of a machine wire? Give an instance with full particulars.*

B says: "The quantity of paper made on it in a given time." This cannot be said to directly influence the life of a machine wire. A large output of course means rapid speed, more suction, more friction, more shake, etc. These influence the life, but the mere fact of making more paper apart from these reasons cannot be said to constitute a real cause, although it is quite evident of course what **B** means when he speaks of the quantity of paper made.

Others have discussed these factors more in detail. "Action of bleach." Of course this should only have to be considered in reference to *presse-pâte* wires, and the latter are coated with tin to withstand the action of the bleach. "The action of antichlor, such as sodium-hyposulphite, where the resulting reaction is the formation of free acid." This is a most important point. Some of the students do not understand this properly. They appear to think that there is little or no danger in the use of hyposulphite, provided it is not used in excess of that necessary to neutralize the bleach. The fact is, however, that it is the action between the sodium-hyposulphite and the bleach which produces free acid. If there is little bleach to neutralize there will be little free acid. If the hyposulphite is used in excess there will be no additional free acid. **B** understands this, and has always shown himself very clear on all chemical questions, but in this question he does not give details of the mechanical aspect. He mentions the action

of the sulphuric acid used for cleaning purposes. This in many mills where it is used carelessly may account for considerable damage, and must in all instances be somewhat detrimental even if carefully used. But it is the choice between two evils, the blocking up of the wire necessitating increased suction and consequent wear on the wire, or corrosion of the wire by acid used in removing this deposit. The sulphuric acid if carefully used assists in prolonging the life of the wire. **B** gives us another cause. The frequent changes of sorts. This undoubtedly is a very important factor. As an instance he gives the following: "Two wires, same quality, one on a machine making an average weekly total of 40 tons, chiefly printings, and good class magazine papers. This wire ran 5 weeks 2 days. No. 2 was on machine making fine writings and banks, output 18 to 20 tons per week. Life 10 weeks." His final remarks are hardly expressed in a way to make the matter clear. "The extra weight and speed of running is the greatest factor, although I have known a rare instance of an antichlor practically destroying a wire in 12 hours, after it had been running a fortnight."

C considers that excess of sulphate of alumina would influence the life of a machine wire more than anything. It is not the sulphate of alumina pure and simple, but it is the free acid that is the chief offender. **C** will bear in mind my remarks about the excess of hypo. not being the cause but the excess of bleach which the hypo. has to neutralize. "I know a mill who changed from hypo. to sulphite of soda, and they found it made a good difference to the life of their wire." All papermakers are presumably agreed on this point. The author knows of several instances, one particularly, in which a change from hypo. to sulphite made a difference between three weeks and three months in the life of a wire. If the bleaching is conducted in the beater as it sometimes is there is perhaps half the original bleach put in still left free. This if neutralized by hypo. may produce a considerable quantity of free hydrochloric, but if the bleach to be neutralized is only a mere trace, the damage through the use of hypo. is not so marked, therefore the change from hypo. to sulphite of soda would in the latter case not result in as much advantage.

D.—There is much in this answer which others would do well to study. "Running at fast speeds with wet stuff and drawing hard at the boxes wears out the wire more than when running at a moderate or slow speed, through the rubbing against the suction boxes. And a heavy breast-roll also wears it out as it strains the wire. If the mesh of the wire is very small, take as an instance

a case when working wet stuff with a 72-mesh wire, the constant rubbing on the boxes will cause the meshes to get closed up, so that they will not let the water through freely. The bottom coucher should be covered every time the wire is changed, and not run for two wires. All the rolls of the wire should be parallel, and the guide roll used for guiding the wire in case of a run and not used to counteract any rolls that may be out of the square. The wire should always be washed when the machine is to be shut for any length of time, so as to clean the meshes of the wire from fibres, etc. Also while the machine is running, a good force of water should be kept directed on to the first roll after the wire leaves the coucher, so that the wire is kept wet all the way across. If the wire is dry at one side it will run into a crease as well as run about. *Strong* sulphuric acid should not be used, as it tends to weaken the wire on the side the acid is run in. If the wire is exceptionally dirty (on edges), when shutting on Saturday night it should be thoroughly cleaned and not left till Sunday night, when the wire will be hard and dry. The wire should be kept covered over with a cloth during Sunday, so that the sun will not dry it hard in one place and leave it wet in another." **D** is one of the few who mention the difference occasioned by the size of the mesh. The fine wires require the most delicate handling, and damage may often be done to them at the time they are put on.

E.—I do not think it can be said that water containing a lot of lime will corrode the wire. It may be of great inconvenience by helping to incrust the wire and to fill the pores up, but the lime salts would not corrode and eat the wire away. Machine wires are deteriorated if the sulphate of alumina "contains too much free acid, that is to say, more than is required to bring the alumina into solution." This is hardly the correct way of expressing it in a chemical sense, because the acid cannot be "free" acid unless there is an excess over and above what is necessary to form sulphate of alumina ($Al_2 3SO_4$), but **E**'s way of putting it is most expressive. If no more acid is used than is necessary to bring alumina into solution, we shall have what is known as a basic of sulphate of alumina, such as is now made by some of the chemical manufacturers. This is not so economical from the point of view of its neutralizing and precipitating power, on account of its containing less combined sulphuric acid in proportion to the amount of alumina it holds in solution than the normal sulphate of alumina ($Al_2 3SO_4$), but it has one great advantage, namely, that it is safe and has the minimum effect upon the machine wire, and, therefore, taking all things into consideration,

might be the more economical to use. It might also be pointed out that it is advisable from the point of view of safety to use a basic sulphate for the tub-sizing. **E** considers that the danger from antichlor ought to be guarded against by washing the stuff long enough so as to remove all but the last traces of bleach. "Wires often go at the seam; this is very often caused by defective vacuum boxes; the seam being perhaps the most prominent part of the wire, comes into more violent contact with the boxes. To get a good vacuum as the pores of the wire get clogged, the machineman finds it necessary to keep raising his boxes, which results in more rapid wear. Of course, the more water the pulp contains, and the thicker the paper, the more vacuum is needed."

The first part of **F**'s answer given in full:—

"When putting on a new wire take great care to have all rolls cleaned, and see that the rolls are all true and level. Put no bottom couch-roll jacket on, for should pulp run up the top couch roll and fall from under the doctor-board it will scarcely make an indent in the wire, whereas if a bottom jacket had been on, the felt being soft, the lumps would indent it very much, and these would soon go into cracks, and the wire would soon spoil; also have plenty of rinse-water playing upon the breast roll and on first roll after paper has been couched; also plenty to blow through the wire to wash out all particles of pulp that have lodged in the meshes. Have the wire guide working right, so that wire runs steady and does not rub the sides anywhere. If working a dandy-roll, take care that it does not run right directly upon the small roll placed beneath it. Start up with the wire not too tight at first, keeping the seam straight. For some time watch the seam of the wire well, to see that it does not get behind or forward at one side.

"In using rosin size there is a tendency for the meshes of the wire to block up, which is very noticeable just outside of the edges of the pulp, and which must be washed out, more especially if you should want to shift your deckels wider; if not removed the outside paper would not run. The best thing that I know of to get this rosin and alum out of the wire is sulphuric acid, diluted, and poured upon the wire roll. This soon removes the block, but it makes the edges of the wire very soft, and is one of the things which lessens the life of a wire.

"Another thing which shortens the days of a wire is the use of hyposulphite of soda. One would scarcely credit the difference there is in using sulphite of soda in place of hyposulphite of soda. I would say wash out all the bleach liquor you can and use

sulphite of soda. It will take a lot more sulphite than hyposulphite to neutralize the bleach, but it will keep your wires a brighter colour. All brass rolls will shine bright down to the press rolls, and the wires will last twice as long as if hyposulphite had been used."

The rest of the paper gives particulars of the chemical reaction which takes place, and equations showing that in the case of "hypo" there is hydrochloric acid formed, whereas in the case of sulphite there is no free acid.

G justly concludes that any accident or carelessness in putting on the wire will reduce its life considerably, as also running at high speed. "The vacuum boxes should also be kept perfectly smooth and level, where the wire passes over them, or they will soon damage the wire. The amount of suction used also influences the life of the wire, and it is much better for the wire to have three or even four vacuum boxes drawing gently than to have only two boxes drawing hard." This is a very wise and practical remark. It is better, undoubtedly, for the sake of the wire to have a greater suction area and less vacuum. A small suction area with a very high vacuum must be a great strain, especially on delicate wires. "Dirt in the paper will soon damage the wire."

Much of **H**'s answer is worthy of study :—

"Generally, the life of the wire depends upon the attention paid to it by the machineman. In putting on a new wire, the first thing is to be sure that the surface of the rolls are all clean, that is, to see that there are no lumps or patches of stuff left on them. Care must be taken not to kink the wire in putting it on, as the bends so produced often develop afterwards into cracks. One of the most important things is to keep the seam straight, and to do this, if the machine is true, is to keep the stent roll at a perfect level, and not to have it too light, but just so that it works in its brasses with a light pressure of the hand. Couch equally, as unequal couching tends to throw the seam out on the edges, and keep plenty of water on the wash roll so as to prevent riding. The length of time a wire will run depends chiefly on the class of chemicals, and whether a bottom jacket is made use of. As an instance of the action of chemicals, I will take the use of hyposulphite of soda as an antichlor. I have seen wire run about six weeks and then start going into cracks, and keep getting worse till it has had to come off, the wire itself being very black. By using a better antichlor, such as sulphite of soda, I have seen them taken off after running 13, 14, and 15 weeks

without a crack in them, and the wire itself always remaining bright. It may be contrary to the opinion of some when I say that there is hardly any difference in the wire marking whether you have a bottom jacket on or not, and by running without one there is never much fear of your wire running into a wrinkle, and lumps and strings do not leave so much impression as they do if you have one on. Another important consideration is the effect of shifting and continually washing the wire with sulphuric acid. It is a great advantage when making several different sizes from one and the same stuff, to start making the widest first and gradually going into the narrowest; by so doing you only have to wash the wire once where you would have had to wash it two or three times. Continual washing deteriorates the edges and makes them slack. Another point I might refer to is the enormous weight of some breast rolls where there is no actual need for it. For instance, where a 4-cwt. roll would suffice and the machine is provided with a 6-cwt. one, the extra weight must have a lot to do with weakening the wire in the course of about 12 weeks."

Take careful note of these final remarks about the enormous weight of some breast rolls. Possibly in this respect the American machines have somewhat the advantage of us. The combined strain upon a machine wire due to the shake, the pull of a heavy breast roll and the suction must be very great.

As I's remarks, especially those referring to the unequal strain on the individual wires, are most instructive, a considerable portion of his paper is given below:—

"One way by which the life of a machine wire may be lengthened is to give it as little straining as possible. The wire should be run as slack as possible without spoiling the sheet.

"The wire being drawn into the vacuum boxes owing to the high vacuum, takes a distinct concave surface; it is then rebent in the opposite direction by the couch roll. This action continually going on must weaken the wire. The same action takes place at the edges of the vacuum boxes, and a wire is often seen to give way in line with the edges of these boxes. To preserve the wire, maintain as low a vacuum as possible.

"The pull on each individual wire should be equal. The best way to judge if this is the cause, is to look at the seam and see if it is in line with the tube rolls. Often it takes the form of an "S" or a "V." This shows that each different wire has not the same pull on it. Some are more strained than others, while some are hardly subjected to any pull at all, something like a set of

violin strings. If the wire is kept properly taut it will last much longer."

K considers that the most important thing to prolong the life of a machine wire is care and attention on the part of the machine-man. Unfortunately, however, he has dealt with only one aspect of the subject. Some of his remarks are given, as they are worth study:—

"The wire itself may be of the best quality and make obtainable, the wire frame perfectly rigid, the wire rolls perfectly true, the stuff properly prepared and with no excess of free acid, and yet a wire which ordinarily ought to run six weeks will not run four, through carelessness in starting. By allowing the stuff to get in too great quantity up the couch roll, and so pass beneath the guardboard, the wire may become marked all round. It may run without giving trouble for a day or two, but it soon requires to be tightened to keep the dimpled and slack parts from crushing the paper as they pass through the couch rolls. This tightening down soon strains the wire, until at last an injured part will no longer hold together, and the wire has to be taken off and replaced by a new one." Causes which shorten the life of a wire are:—"(1) Acidity of the pulp, due to the chlorine being imperfectly neutralized or washed out. (2) Length of wire; as, other things being equal, a few feet extra length adds considerably to the life of a wire. (3) The quality and quantity of paper made; good paper, as a general rule, needs more shake and suction in passing over the suction-boxes, thus straining the wire, and a large output of paper requires higher speeds. The wire will also tend to wear out sooner if not set right at the beginning."

M gives a fairly long answer, but he does not shine in this subject as he does in some others. He appears to show a want of that practical knowledge and experience which some of the other students have shown.

The first portion of his answer, however, is interesting:—"A long wire will last longer than a short one because (1) it passes a fewer number of times over the pump boxes and between couch rolls in a given period of time; (2) With a long wire it is not necessary to give so much shake as with a short one, as one can work more water on a long wire; (3) It is not necessary to draw so hard with pumps on a long wire." "Life will also depend upon the class of paper being made. With 'wet' stuff and thick papers the wire must be worked tighter to get the water out, and therefore will not last so long as when working on free stuff and thin papers. Pressing hard on couch rolls will shorten

life. This is sometimes necessary, especially on machines where there is not much drying power." He then proceeds to give particulars of the reaction between hypo. and bleach, from which he calculates the amount of free hydrochloric acid in a given weight of half-stuff, and he concludes from this that the acid could hardly have any effect on the wire. It is extremely dangerous to base a conclusion on such an argument, the details of which have evidently been derived from text-book knowledge. Practical experience reveals a very different state of things. There is, however, one practical point, viz. the alkalinity of the bleach, which must to some extent neutralize any free acid formed during reaction. He next proceeds to give particulars of Gemmell's work (PAPER TRADE REVIEW), in which it is shown that the action on the wire is very much increased by the free acid in the alum. The author does not think that there is an exact parallel between Gemmell's experiments and what takes place in practice. The extent of the action must to a large measure be influenced by the movement of the wire. The wire comes in contact with the pulp containing the chemicals, and on its return is rapidly rinsed with water. It is exposed also to the air, and so kept in constant motion. There is also the possibility of a chemical reaction being accelerated by the stuff being heated as it comes on to the wire. There is another factor also which operates on a machine, to some extent at any rate, viz. :—galvanic action. We have a circuit between two dissimilar metals or alloys in the presence of an electrolyte. It is highly probable, therefore, that taking all these matters into consideration, the action as it takes place in practice would be different from the action as noted by Gemmell in his interesting and instructive experiments, which should be studied by all who are interested in the subject of the life of machine wires, but it is necessary to avoid placing any false construction on them, or forming too definite conclusions as to what would take place in actual practice. "Backwater should contain only a very slight excess of alum to ensure all the size being precipitated and to mordant the dye, but sufficient to turn blue litmus a faint red." He would have done better to have said "sufficient to have turned neutral glazed litmus papers a faint red." The latter papers would show the least possible acidity, whereas many of the former papers require a very decided acidity to give a red. "Wires mostly come to an untimely end through accident, such as couch roll covers bulking, or ridges being formed through various causes, such as stuff gathering on the 'stenting' rolls or extraneous matter getting on couch roll covers. The writer

remembers a case of a wire requiring removal after having run only a fortnight, owing to a ridge which was formed by a piece of hard 'nap,' or little woolly lump found afterwards under the bottom couch roll cover."

N.—"Keep the wire comparatively slack and seam straight, jacket well fitting, and couch as light as consistent."

Q argues on somewhat different lines to the others :—

"The first thing is to find any defect in the new wire, such as tight edges or slack middle, or *vice versâ*, and when you have found the defect adapt the working of the wire to that defect, and when you have got it to answer true to the guide there is not much to fear in the ordinary running. Drawing evenly at the boxes is most important, anything to cause friction must be removed, and all doctors, etc., seen to, so that no pulp can travel round with the wire. This is very dangerous should any get lodged and accumulate before it is noticed—a ridge in the cloth is the result, which is a serious matter, especially when making thin paper. Wash well down whenever changing, and especially for the week-end, and always let the wire out a good few rounds every week-end ; in fact, you must nurse it if you would keep it."

R gives a long answer. It contains many points that have already been discussed. "Even the alum itself when used to excess is injurious, and I am of opinion that with the recent introduction of stuff-catchers, such as the 'Fullner,' where the back-water returns to the machine, either by the beaters or the mixing box, the effect will be more marked. The quality of water used in various mills is so different that the quantity of alum must be varied accordingly. Thus where the water is hard there is usually an excess required to neutralize the salts it contains. . . . Too great care cannot be taken in regulating the quantity used and the choice of alum itself." He is arguing on a false basis. There is no reason whatever that the effect of alum should be more marked when using a stuff-catcher. A stuff-catcher is also an alum-catcher, for it enables the water to be used over again which would otherwise have run to waste, and in proportion as it saves water, so can the alum be reduced in quantity. If, therefore, the alum is reduced to the extent of that saved by the stuff-catcher, the effect will not be more marked, but should be the same as formerly. Then, as regards the quality of the water varying and necessitating different quantities of alum : A water containing, say, 17 grains per gallon of carbonate of lime (Kent water) would require double the amount of alum to neutralize it

as compared to a water containing $8\frac{1}{2}$ grains. But if in both instances a sufficient additional quantity of alum is used to overcome the hardness of the water, there is no reason why one should act more on the wire than the other, as in both cases the alum is neutralized. It is the excess over and above what is necessary to precipitate the size, to neutralize any alkalinity in the pulp, and overcome the hardness of the water which may prove detrimental. "I also think that by using a jacket on the under couch roll a good deal of friction is overcome." This is hardly likely to be true. There are reasons for the use of a jacket on the under couch roll, but this is hardly one of them. The reasons against a jacket from the point of view of the life of the wire have been stated in previous answers. **R** argues from the equation for sodium hyposulphite that only 15 per cent. of HCl is formed, and he does not consider this a large quantity, and therefore less likely to be injurious than the alum. He has fallen into the error of thinking that the harm caused by the antichlor can be minimized by avoiding an excess. This argument has already been dealt with.

S points out the difference in the life of wires by different makers:—"Some makers' wires will not run more than three weeks with us, but will run six or eight weeks in another mill using different water, but making the same class of paper. Other makers' wires will run six or eight weeks with us, or sometimes longer." There is no doubt something more in this than the quality of water.

U's paper deals with some different aspects of the question:—

"The speed at which a wire is run is one of the most important factors in the life of a wire. The greater the speed the more strain on the wire. A wire running on writings lasts much longer than a wire on a news machine at a speed of from 250 to 500 feet per minute.

"It is necessary to make the suction boxes draw harder when working wet stuff, and the wire is therefore kept hard on to the boxes, resulting in the wearing of the wire, and therefore shortening its life.

"When acid alum or acid is used in bleaching, and not thoroughly exhausted or washed out, or if stuff is acid from any other cause, the wire which is of an alloy of copper, zinc, lead, or tin, is gradually attacked, and therefore much weakened. It is a practice in some mills to wash the wire with dilute acid; this, if overdone, has a very injurious effect. Wires have also a much shorter life when a heavy breast roll is used, there being so

much more weight to be turned by the wire. When the top couch roll leans too far back on the wire, the wire has to support part of the weight of the couch roll; this tends to strain the wire. Apart from wear, a wire is soon filled up with fine stuff, particularly mechanical wood pulp, which causes the paper to look full of markings—this often necessitates putting on a fresh wire. I will take as an instance in the life of a wire the case of a wire running on printings and news: On a machine making printings at a speed of 120 to 160 feet the wire lasts from 7 to 10 weeks, while on a news machine running at 300 feet it is considered a good wire if it runs a month. If the shake is excessive the life of the wire is shortened, owing to the slight twist backwards and forwards to which it is continually subjected.

"It is taken for granted that the wire is evenly stretched, and well seamed."

Some portions of V's paper are given:—

"The life of a machine wire is chiefly influenced by the acidity of the water or of the stuff which is running on it. That is to say, the alum used in the precipitation of the size has to be considered.

"Mr. Gemmell has shown that the effect of 4 per cent. of free sulphuric acid (such as could be obtained by using excess of an alum of the character of alumino-ferric) causes very serious deterioration of machine wires, but that the use of a sulphate of alumina free from acid does not affect the wire appreciably until it obtains a strength of 112 grains per gallon. He also showed that solutions containing a large percentage of bleach neutralized with hyposulphite have considerable action on the wire, due to the formation of hydrochloric acid. Thus the wire varies in life according to the character and amount of alum used.

"It frequently happens that too much alum is used, or that there is too much suction at the boxes. Sometimes wires develop ridges or wrinkles, which widen to such an extent as to render the wires useless.

"Wrinkles are generally caused through the wire running too slack, and ridges through running too tight. It is safest to run the wire as slack as possible, but not so slack as to cause the wire seam to cut the paper when going through the coucher.

"I know of one instance where the change from the use of an excessive to a normal quantity of alum has had the effect of lengthening the life of the wire three and four weeks, and also where in the case of a *presse-pâte* the intelligent use of antichlor, by giving the man a packet of starch iodide papers, has made a

difference of six and seven weeks in the length of the life of the wire, to say nothing of the felts and jackets."

W states: "In places where rock alum is used wires last longer than where sulphate of alumina is used." This raises an important point. The amount of free acid in commercial sulphate of alumina is far less than it used to be about twelve years ago, and it has become gradually less as the manufacturers have better understood the preparation of sulphate of alumina. The author has met with samples containing 5 per cent. of free acid. This, of course, was exceptional, even at that time; but years ago the free acid was often as much as 1 per cent., and now it has diminished to a very small amount indeed—so slight, in fact, with the best makes of sulphate of alumina that there is very little difference in this respect between crystal alum and sulphate of alumina. How can these two substances affect wires differently unless they differ in the amount of free acid they contained? There is now practically no difference between the two, both being practically free. With the basic sulphate of alumina at present on the market we may be safe in assuming that there is no free acid at all. Crystal alum was formerly used in preference to sulphate of alumina, because of its greater freedom from iron. But in this respect also, sulphate of alumina now runs crystal alum very close, and contains practically no iron. As crystal alum is more expensive than sulphate of alumina in proportion to the amount of work it will do, the latter is almost universally preferred for ordinary paper mill work.

None of the answers contain any reference to machine wires from the maker's standpoint. The author made some remarks on this subject in lecture No. 6, delivered at Croxley. Now that the wire is drawn through a diamond die it preserves a circular contour and remains smooth and regular from end to end. Formerly wire was drawn through a metal die, which gradually enlarged and became irregular in section; the consequence was that the wire drawn through the die became varied in section and was more or less rough. There must be considerable advantage in having machine wires woven from wire that is absolutely uniform and smooth. Any irregularities must tend to block the wires, as small particles of fibre, etc., will cling more readily. As a wire becomes corroded by the action of alum, etc., it must have a greater tendency to block up, through the wire becoming rough and causing fine particles to detach themselves from the web of paper. Many explanations have been given and analyses made of machine wire deposits, a subject which is very nearly related

to the life of the machine wire. This question has, in the author's opinion, been dealt with, too much from a chemical point of view and too little from a mechanical point of view. The various analyses of the machine wire deposits have differed considerably one from another. As a consequence chemists who have undertaken these investigations have come to different and conflicting conclusions as to the cause of machine wire deposits. No doubt greater light is to be thrown on the matter by an examination of the physical conditions of the machine wire itself (roughness, etc.), and the physical condition of the wet web of paper. Sometimes the deposit consists of one thing and sometimes of another.

Remarks by Dr. Stevens of the effect on the wire of using "hyposulphite," as an antichlor:—

"I cannot think that the small quantity of acid liberated by the use of 'hyposulphite' as an antichlor can more than partly account for the destruction of the machine wire. Although acid is liberated according to the equation generally given, a great part or the whole will be neutralized by basic substances, such as the lime in bleach and water, which are always present. Furthermore, it is worthy of note that the effect of using hyposulphite is to blacken the wire; this is referred to in **H**'s reply, and more than one student refers to the difficulty in keeping the wire clean. This is not what would be expected if the action on the wire was due to acid. I should expect acid to brighten the wire, even although it acted upon it. I think the fact that the wire tends to blacken will give us a clue, as copper and other metals, as is well known, yield black sulphides. Further, hyposulphite is a substance very rich in sulphur, as may be seen in contrasting its formula with that of sulphite, thus—

Hyposulphite, $Na_2S_2O_3$ Sulphite, Na_2SO_3.

This extra atom of sulphur is readily split off, *e.g.* by the action of acids; thus if a little acid (HCl or H_2SO_4) be added to a solution of hyposulphite and set aside to stand, sulphur is gradually deposited. I am therefore led to the conclusion that a certain proportion of hyposulphite is decomposed in other ways than that generally accepted, with the formation of sulphur or sulphide. The sulphur will be contained in a finely divided state in the stuff, and may even be produced by the hydrochloric acid liberated in the decomposition of another part of the hyposulphite added. This sulphur would rapidly act on the copper contained in the machine wire, with the formation of black or dark coloured sulphides resulting in a rapid deterioration of the wire."

CHAPTER XVI.

EDGE RUNNERS.

Mode of action—Scope of utility—Effects on different fibres—Power consumption.

QUESTION 16.—*What is the action of edge runners, and for what special purposes would you recommend their use?*

B gives a very fair answer. The point on which he lays particular stress, and which distinguishes the action of the edge runners from almost any other machine, is the slip occasioned by the difference in the inside and outside diameter. **B**'s description is a little bit confusing, but he evidently has a full knowledge of this slipping action in his mind. The maximum slip of a pair of edge-runner stones can easily be calculated. We have merely to take the distance of the internal face of stone from centre of pan, and also the distance of the external face of stone from centre of pan. From these two measurements we can easily calculate the circumference of the two circles which the internal and external faces of the stone describe respectively when making a complete revolution of the pan. Assuming that the stones grip on the external edge but slip on the internal edge, the slip would be represented by the difference of the circumferences of the external and the internal circles. Now, supposing that the stones grip on the inner edge, they will, of course, be describing the same path as before, but revolving on their own axes at a lower rate. The slip would still be represented by the difference between the two circumferences of the circles. The amount of slip would, however, be minimized if the grip of the stones were situated somewhere between the inner and outer edges.

"The vertical stones, or rolls, or wheels of an edge runner or kollergang are placed on the ends of a spindle, which is worked by the gearing to make a circuit on the horizontal stationary

stone in the pan. The stones are loose on the spindle, so as to revolve during the circuit. The circumferences of the insides and outsides of the stones are equal, but they traverse unequal circumferences on the foundation stone. Therefore, as the stones do not travel in a straight line, but are forced round a circle, if the inside grips, the outside slips, and a tearing and grinding action is produced, or it may be explained more fully as follows :—

"The inside and outside circumferences of the vertical stones are equal, but the outside face of each stone travels on a circle of greater circumference on the foundation stone than does the inner face. The consequence is that as in any revolution of the stone the outer and the inner edge travel an equal distance in space of time and an unequal distance on the foundation stone, a slip must take place either on the outer or inner circumference, depending upon the position of the grip between the vertical and foundation stone. The action on the stuff is to force it from the insides of the stone to outsides. Guide blades fixed to the revolving frame are set to bring the stuff back to the stones again.

"By resolving the motion of a wheel into its component parts we get per revolution a simple rolling in distance equal to circumference of wheel, combined with a revolution of wheel (or stone) upon a vertical axis (virtually), which produces the grinding and tearing of stuff respectively.

"Until recently the edge runner was the apparatus universally used for the preparatory treatment of 'broke' and bought paper shavings and sometimes mechanical wood. It is now obsolete in up-to-date mills (?). Patent kneaders and cornet breakers, etc., have superseded it. It is still largely used in Germany, especially in chemical pulp mills, for reducing knots and other purposes.

"In reply to the last part of the question, I should use edge runners for the materials mentioned, but only, of course, where circumstances did not permit of the use of the more modern appliances referred to."

B is undoubtedly prejudiced in favour of other appliances. He might, however, have made out a somewhat better case in favour of edge runners. For many purposes there is no doubt they are becoming obsolete, but their action is different from any other disintegrator, and on this account they are still to be preferred for certain work. It is as well to point out here one or two points which have not been dealt with by any of the students. The fact of the edge-runner action being intermittent admits of a perfectly regular mixture being produced at each

charge. Thus, it is easy when mixing dry pulp with water to obtain a mass containing whatever proportion of water may be required within 1 or 2 per cent. In a continuous machine, such as the cone breaker, a much larger proportion of water is needed to bring about the disintegration, and the pulped material varies considerably in the amount of water it contains, depending as it does upon the relative supplies of water and shavings. This is of no consequence in some mills, but in others, where it is necessary to know exactly the constituents of the furnish, it may result in considerable difficulties. In the case of Wurster's kneader this difficulty does not arise. The other points of difference will be explained as we deal with the other papers.

C describes the edge runners as having a crushing action, and recommends their use for crushing old papers that come into the mill.

D remarks, "The edge runner bruises out the fibres and makes them very much finer. Broke from the edge runner helps to make a close sheet on the machine, and also helps to give a better retention of the loading."

E recommends them for "pulping up mechanical and broke from machine cutters and finishing house." He says that "if an edge runner were not used in a mill the waste papers would have to go to the poachers."

F's paper is below :—

"The action of edge runners is to work up the broken papers of a mill. It consists of two large granite stones, revolving round in a granite-bottom pan with iron sides, provided with two sets of scrapers, one of which is to keep scraping the papers under the wheels, the other is to scrape right on the stones and rake out the contents to the hole when emptying the pan. The stones are driven from underneath, and the stone wheels are made so that they can rise and fall with the thickness of stuff in the pan. The pan is 10 ft. diameter and 18 in. deep. The granite bedstone, 6 ft. diameter and 12 in. thick. Two granite runners, 6 ft. diameter, one wider than the other. Bevel driving gear, 90 and 12 cogs, 2 in. pitch, 5 in. wide ; fast and loose pulleys. Speed of the runner, 14 revolutions. Speed of shaft equals 105 revolutions per minute. Size of pulley, 42 in. diameter by $7\frac{1}{2}$ in. on face. Weight, about 16 tons. Quite 5 horse-power with full load. This is shortly a description of a good edge runner. The special purpose for which I would use an edge runner broke is in making a thin bank-paper, where closeness is required and the fibres are long. When using the broken papers that have been crushed by the stones

and ground up very fine, the fine fibres float along the wire and settle down between the long fibres and fill up the small spaces between the long fibres, making a close and evenly-made sheet of paper. Edge runners are also useful for grinding up sulphite and soda wood, to reduce this material to a finer state and to make it work wetter on the machine—as in the finer printing and news mills. From the point of view of economy, I fail to see much advantage in using edge runners in preference to scalding papers, except that edge-runner broke retains the loading that was originally put into it, but which is partially lost in the process of scalding. I have found papers that have been ground up by edge runners to need as much clearing in the beaters as scalded papers do, because they are so very 'hard ground.' The power required to drive the stones will more than compensate for heating the water for scalding."

G remarks, "The action of edge runners may be described as crushing and grinding. They take a good deal of power to drive, and I don't think they can be employed advantageously except for waste papers. I have seen wood pulp (mechanical) put through a Keir and then through a Kollergang, but I don't think the result obtained justified the power required." I think he is right in regarding the power required for edge runners as being very much against their use. I should certainly think that the large amount of power they absorb for the amount of work they do is the chief reason why they have been so much discarded.

H's answer :—"The action of edge runner or Kollergang is to grind up broken papers, and to retain all the ingredients originally present in the paper, which it is just possible might come out in the scalding. The only cases where, in my opinion, the edge runner is used with advantage is for working up shavings for printing papers, or broke for strong banks or loans. In such cases the stuff is worked long, and the very fine fibres from the broke will settle in between the long fibres on the machine wire under the action of the shake and suction. Edge-runner stuff, being very fine, has a tendency to float on the top, and so fill up the weak places, and helps to make a more even-looking sheet. I don't see where else the edge runners can be used with advantage in ordinary papers, on account of the cost of working.

I's description of the action of an edge runner, as being a rubbing one, is fairly good. The shearing action, due to the slip and roll of the stones on top of the stuff, must produce a certain amount of rubbing action of one particle against another.

K reminds us that the edge runner enables us to produce

broke without losing the sizing and colouring. He is the only one, I think, who mentions that the edge runner can be used with advantage for grinding up mineral matter, such as satinite, which if added to the beater in a dry and caked condition would show up as small particles in the finished sheet. Other mineral matters are treated in a similar way.

L.—A crushing and grinding one. The stones should weigh not less than two tons each, in my opinion, for effective work.

M remarks that "broke is generally steeped in water, and sometimes simply moistened before being ground."

N ascribes to the edge runners a grinding and crushing action. "In thin papers, by using edge-runner broke, spaces are filled up. It assists in carrying the loading; being so fine the fibres float on the surface, and are drawn down by the suction of the pumps into the spaces. Edge runners are used in softening mechanical wood to assist the beaters. Where a large proportion of mechanical wood is used and beating power is short, they may be useful."

Q writes somewhat on the lines of the foregoing, but I think it only fair to give the following extracts from his answer:—

"A crushing action, the material being under the action of the rollers almost constantly, and the fibres are therefore rendered uniformly fine, so fine that they float on the water and are very sensitive to the action of the shake. I should recommend the use of edge runners for all filling-up stuff, papers, box-cuttings, pulp (mechanical), etc., as the beater-roll cannot possibly produce such material to the same perfection as the edge runners."

R points out that edge-runner stuff could not be used for paper alone, as it is too fine, and considers that it produces a good filler for papers where appearance is not of much consequence. "They overcome knobs and any hard substances in the material worked." Other points of advantage mentioned have already been dealt with in other papers.

S.—"It has a grinding action which separates the fibres, but does not cut them like a beater-roll. They are used for broke papers and sometimes wood pulp, where you don't want the length of the fibre injured." This hardly gives a correct impression. It is almost impossible to avoid bruising the fibres, and with edge-runner broke, as we well know, the individual fibres are often bruised out of all recognition, so that they cannot be distinguished under the microscope. The reason of this is largely because ultimate fibres when crushed and pressed have a tendency to split into what is known as fibrillæ. Each fibre when crushed will

sometimes split or splinter into smaller particles along its length. The fibres if not actually split so as to be separated are often flattened to the extent of being entirely unrecognizable. Hence the peculiar qualities of edge-runner broke.

U should not have any difficulty caused by grit coming from the stones if they were properly cleaned before use :—

" Edge runners have a *drawing* out and *crushing* effect on the fibres, exactly the effect required for producing the fibre in the most advantageous state. The drawing out is produced by the slow movement of the stones, and the crushing by their weight. I should chiefly recommend their use for waste papers, where it is important that the fibres should not be reduced in length, and also because of their easy disintegration ; for *hard dried* mechanical wood, because of the difficulty of thoroughly beating out all the fibres when in this hard state. This applies to fibres containing knots, and hard fibre, as bamboo and megass, etc. The use of edge runners is not to be recommended for better-class papers on account of the mica and other grit coming from the stones and appearing in the finished paper. Straw and esparto are not often treated in the Kollergang, as these fibres may be disintegrated while being washed and bleached ; and are also liable to roll up into small balls."

V.—We reproduce a portion of **V**'s answer :—

" The passage of the stones over the material in process of being crushed is threefold :—

(1) Crushing effect due to the great weight of the stones, which weigh several tons.

(2) Rolling action tending to draw out and extend the fibres lengthwise and sidewise.

(3) A shearing action due to the twisting and crushing action of the stones as they move in their circular path.

" The effect upon the stuff in process of pulping is a simultaneous crushing, twisting, and flattening out action.

" I should recommend the use of the edge runners for the disintegration of mechanical pulp, and the pulping up of broke papers.

" The edge runner is in some mills in the course of being supplanted by disintegrators on the style of the Partington disintegrator, which, although they get through more work, do not do it so effectively. It is another comparison on the lines of that between the Hollander and the refiner engine. The fibres under the action of the edge runner can be got very fine, and for this

reason stuff treated in the Kollergang has the effect of raising the retention of loading."

W owns he has had no experience with edge runners, but from reading he gathers that their action would be too drastic for the majority of fibres used in papermaking. This is a very wise conclusion. Even if edge runners could be run economically their action on the fibres is such as to render them unsuitable for a great deal of work, but where a drastic action is needed, as in instances above cited, and for special effects in paper, the edge runner is to be recommended.

The author wishes to revert once more to the action of the edge runner, because he thinks that we should give it a little more study before leaving the subject; we must assume that it slips either on the inside or outside surface. If it grips on the outside and slips on the inside, we have a motion at the inner edge equal to a velocity due to grip on outer edge. This must result in a forward slip, or a slip in the direction in which the stones are travelling. We might describe this as a + slip, since it adds to rather than takes from the forward motion of the runner.

Let us now assume, on the other hand, that the stones grip on the inner edge and consequently slip on the outer edge. The stones would now have a velocity due to grip on the inner but travelling on the outer circle. The outer edge is now dragging behind, as it were, and the slip is now a backward or minus one. In either case, however, the amount of slip would be the same. If the amount of slip is measured in feet per minute, one arrives at in either case an equal amount of so many feet, plus or minus slip per minute, as the case may be. The amount of the slip in either case is got by ascertaining the difference between the outer and inner circumference, as already described, and multiplying this figure by the number of complete revolutions round the pan to obtain the slip in feet per minute.

Let us, as an instance, take the particulars as given by **F**. We have a granite bedstone of 6 feet diameter. For the sake of argument we must assume (although we may not be strictly correct) that the outer edge of each stone corresponds exactly with the edge of the granite bed, and that the two stones are of equal thickness. The outer edge of each stone would at each revolution describe a circle of 6 feet diameter, or 3 feet radius. This circumference would be equal to a distance of $6 \times 3{\cdot}1416 = 18{\cdot}85$ feet.

If the stone is 1 foot wide, the inner surface would travel round on a 5-foot diameter circle, having a circumference of $5 \times 3{\cdot}1416 = 15{\cdot}71$ feet.

We have a difference between the two of $18{\cdot}85 - 15{\cdot}71 = 3{\cdot}14$ feet. The runners make fourteen revolutions, therefore the slip is $3{\cdot}14 \times 14 = 43{\cdot}96$, say 44 feet per minute for each stone, either plus or minus, as the case may be.

It follows, of course, the slip is enormously increased by increasing the thickness of the stone for a given diameter pan. The action of the slip is not unlike that of a pair of horizontal millstones, as the "slip" or motion of one surface against another increasing from nothing at the point of the "grip" to its maximum at the edge of the stone, corresponds to the grinding action of one millstone revolving on another, where the slip is nothing at the centre and at its maximum at the circumference. The edge-runner action to the extent of the slip must be of a grinding or milling nature. The appearance of the stuff in the pan demonstrates how the slip takes place. There is a want of continuity in parts of it exemplifying where the slip is at its maximum. The action of edge runners is furthermore intensified by the whole weight of the stone bearing on the point or line of contact.

Of course the power absorbed by the runners varies enormously with the amount of charge, and the kind and condition of material under treatment, as well as with the speed at which they are run. When the machine is running empty, provided the bearings are all right and the machine is in good order, very little power is absorbed. It might be a very extravagant machine for some materials but comparatively economical for others. Dynamometer reading of power absorbed with edge runners under varying conditions would undoubtedly throw considerable light on the subject. The action of the runner is further intensified by cutting groves in the stone and bed, or by having the surfaces roughened in some way. Edge-runner treatment has the effect of making the stuff work wet, which can hardly be claimed for continuous disintegrators.

INDEX.

J

K

L

M

N

O

P

THE END

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